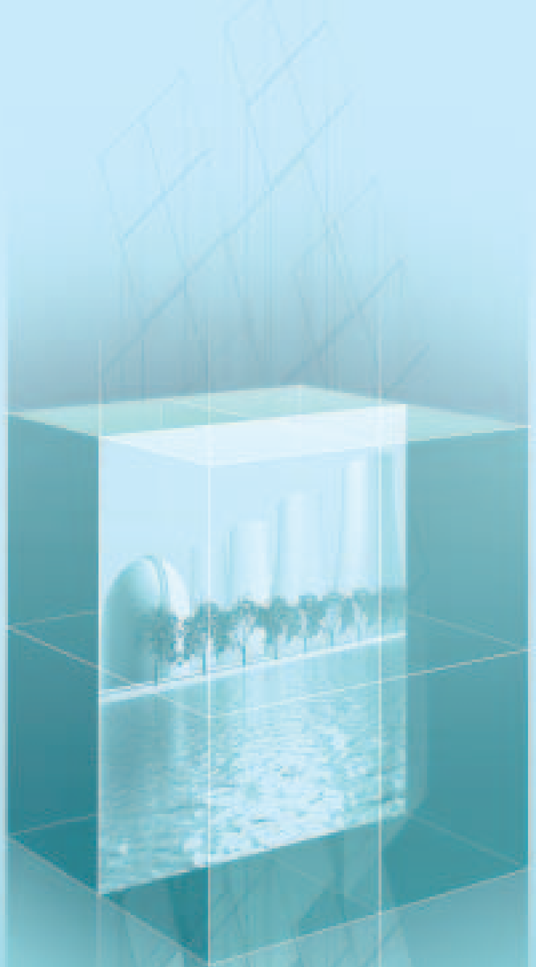

Risk informed decision making

Influence of external factors on safety

Safety of fuel cycle facilities

Safety of research reactors

Safety performance indicators

Topical Issues in Nuclear Safety

Proceedings of an
international conference
Vienna, 3–6 September 2001

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish standards of safety for protection against ionizing radiation and to provide for the application of these standards to peaceful nuclear activities.

The regulatory related publications by means of which the IAEA establishes safety standards and measures are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (that is, of relevance in two or more of the four areas), and the categories within it are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides.**

Safety Fundamentals (blue lettering) present basic objectives, concepts and principles of safety and protection in the development and application of nuclear energy for peaceful purposes.

Safety Requirements (red lettering) establish the requirements that must be met to ensure safety. These requirements, which are expressed as 'shall' statements, are governed by the objectives and principles presented in the Safety Fundamentals.

Safety Guides (green lettering) recommend actions, conditions or procedures for meeting safety requirements. Recommendations in Safety Guides are expressed as 'should' statements, with the implication that it is necessary to take the measures recommended or equivalent alternative measures to comply with the requirements.

The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA.

Information on the IAEA's safety standards programme (including editions in languages other than English) is available at the IAEA Internet site

www.iaea.org/ns/coordinet

or on request to the Safety Co-ordination Section, IAEA, P.O. Box 100, A-1400 Vienna, Austria.

OTHER SAFETY RELATED PUBLICATIONS

Under the terms of Articles III and VIII.C of its Statute, the IAEA makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety and protection in nuclear activities are issued in other series, in particular the **IAEA Safety Reports Series**, as informational publications. Safety Reports may describe good practices and give practical examples and detailed methods that can be used to meet safety requirements. They do not establish requirements or make recommendations.

Other IAEA series that include safety related publications are the **Technical Reports Series,** the **Radiological Assessment Reports Series,** the **INSAG Series, the TECDOC Series**, the **Provisional Safety Standards Series**, the **Training Course Series,** the **IAEA Services Series** and the **Computer Manual Series**, and **Practical Radiation Safety Manuals** and **Practical Radiation Technical Manuals**. The IAEA also issues reports on radiological accidents and other special publications.

TOPICAL ISSUES
IN NUCLEAR SAFETY

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

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FOREWORD

In 1991, the IAEA organized an international conference entitled ‘The Safety of Nuclear Power: Strategy for the Future’. Recommendations from that conference prompted actions in subsequent years to advance nuclear safety worldwide. One of those actions was the establishment of the Convention on Nuclear Safety, which entered into force in October 1996. The first review meeting of the Convention’s Contracting Parties was held in April 1999. The meeting identified a number of external factors and circumstances that could have a significant impact on nuclear safety. These included: (a) deregulation of electricity markets; (b) maintaining competence in industry, regulators and research institutions; and (c) lack of economic resources in some countries.

In 1998, the Agency held a conference on ‘Topical Issues in Nuclear, Radiation and Radioactive Waste Safety’. The nuclear safety issues discussed during that conference were: (i) safety management; (ii) regulatory strategies; and (iii) backfitting, upgrading and modernization of nuclear power plants. Senior nuclear safety decision makers at the technical policy level reviewed these issues and formulated recommendations for future actions by national and/or international organizations. On the safety management issue, recommendations were made to monitor safety performance by using indicators. Recommendations on the regulatory strategies issue indicated the need for further work on utilizing probabilistic safety assessment and on optimizing the prescriptive nature of regulations, as well as on the future availability of competent professionals.

Substantial progress has been made, and continues to be made, by Member States in enhancing the safety of nuclear power plants. At the same time, more attention is being given to other areas of nuclear safety. The safety standards for research reactors are being updated and new standards are planned on the safety of other facilities in the nuclear fuel cycle.

In the light of these developments, it was considered appropriate to convene another conference on the following current topical issues:

— Risk informed decision making,
— Influence of external factors on safety,
— Safety of fuel cycle facilities,
— Safety of research reactors,
— Safety performance indicators.

The conference had the objective of fostering the exchange of information on these topical issues in order to consolidate an international consensus on these issues, on the priorities for future work and the on needs for strengthening international co-operation, including recommendations for future IAEA activities.

The conference discussed the topical issues on the basis of topical issue papers prepared in advance by a group of experts in each of the areas. Each paper contained specific questions for discussion by the conference. A rapporteur presented a summary of the report. Additional information was provided by keynote presentations and lead-in discussion statements. Participants were also invited to submit contributed papers. These were printed in advance and were made available to all participants. Many of the contributed papers were also presented in a poster session. The reports from the rapporteur also summarized relevant items from the contributed papers. The programme was supplemented by a panel discussion on maintaining competence and by presentations on safety culture, communication and other views on risk management.

Although the topical issues focused on aspects related to nuclear power plants, fuel cycle facilities and research reactors, the recognition of many common issues between these facilities was considered an important element of the conference. The essential role of the management of safety and safety culture in ensuring the safety of nuclear installations was repeatedly highlighted as the most important common element, and the IAEA was encouraged to strengthen its activities in this area.

The conclusions from the conference offer detailed recommendations on many of the issues discussed. They will be used in the formulation of future IAEA safety projects. Some interesting features that emerged were as follows:

— There was broad agreement that where the capability exists, risk informed decision making can be a significant enhancement to nuclear safety and the safety focus.
— With regard to external factors, it was revealed that in cases where the achievement of strong business performance was recognized to be a natural result of strong safety performance, market liberalization might enhance safety.
— For fuel cycle facilities the conference suggested that while the IAEA could provide safety services to Member States, the development of appropriate safety standards was a prerequisite to providing these services.
— Organizations responsible for research reactors should develop strategic plans on the future utilization of these reactors, which will help in making decisions on whether or not to terminate operations or decommission reactors in extended shutdown.
— While continuing to provide a range of courses, the IAEA should also place emphasis on helping countries to build their national infrastructure for sustainable education and training programmes. It was recognized that research reactors are being under-utilized, but they could become valuable resources for training and practical experience, especially if they were supporting regional centres for education and training.

— A three tier approach was considered for the development of a possible framework for safety indicators, first focusing on the needs of the nuclear facility, then on the regulatory bodies and later on the public. The IAEA should continue its work to ensure that definitions of safety performance indicators allow their effective use for nuclear power plants, research reactors and other nuclear fuel cycle facilities.

These proceedings contain the topical issue papers, keynote papers, lead-in discussions, special presentations in the opening and final sessions, statements of the panel members and conclusions of the sessions, conclusions of the panel discussion, and the Chairman's closing report. A CD-ROM containing the contributed papers can be found in the back of this book.

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OPENING SESSION

Chairperson

A. CARNINO
IAEA

OPENING ADDRESS

M. ElBaradei
Director General,
International Atomic Energy Agency,
Vienna

Let me welcome you to this important conference on nuclear safety. I cannot overemphasize the importance that we here at the IAEA attach to nuclear safety. We are aware that the future of nuclear power rests squarely with public perception of this important energy source as being safe. So when we discuss nuclear safety we are really discussing in a way the future of nuclear power — something we need to keep very much in mind. This is an area, as we all know, where the public is very sensitive. If an incident or accident related to nuclear safety occurs, the reaction is much stronger than that to an accident in any other technology. So we need to work hard not only to make sure that nuclear safety is maintained at the highest level, but also to ensure that civil society and the public at large accept and understand that nuclear safety is in fact sufficient for the international community to continue to make use of the nuclear option as a valuable source of energy and electricity.

As some of you may know, energy regulation or safety regulation was initially intended to be part of the overall mandate of the IAEA, similar to its international verification of the peaceful use of nuclear energy. In its Statute, “safeguards” meant both verifying the peaceful use of nuclear materials and verifying safety. But that concept, which was developed in 1957, was not pursued. Conventional wisdom at the time decided that, unlike the case of verification of the non-diversion of nuclear material, countries had a vested interest in ensuring that nuclear safety was maintained at high levels, so there was no need for international oversight. Chernobyl clearly shattered that assumption. After Chernobyl, we realized that safety was not just a matter of good intention. All countries have the intention to maintain nuclear safety at a high level, but not all countries have the necessary expertise or resources. Chernobyl also taught us in a dramatic way that safety is not simply a national concern, because accidents have significant transboundary implications. There is, therefore, an international dimension in ensuring that safety is maintained at a high level — not only in one’s own country but around the globe. As I have said repeatedly, any weak spot — any accident, anywhere — will have a crippling impact on nuclear energy everywhere.

Since Chernobyl, the IAEA’s programme in the area of safety has been significantly revised. We have tried to work in three basic directions. The first is to develop international conventions, which contain legally binding obligations to be followed in different areas of nuclear activity. Two of the most important conventions developed are the Convention on Nuclear Safety, which applies to power reactors, and the Joint

Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management. These are in addition, of course, to the post-Chernobyl conventions on assistance and notification in the event of a nuclear accident or radiological emergency. Although frankly not as strong as I would have liked them to be since they are the result of compromise, these conventions are important. However, a major concern is the lack of universal adherence. Ratification has been very slow. For example, some countries that have power reactors are not yet party to the Convention on Nuclear Safety. The Joint Convention has just entered into force, but with only 27 Parties so far we are still far away from universal adherence. This is an issue you should look at: why countries are not adhering to these safety conventions as they ought to do.

Again, I would compare this to the area of verification and the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). The NPT has 187 members — practically the entire international community — but the numbers for the safety conventions are still very modest. We need to take stock of why that is happening and try to improve the situation.

There are, of course, other areas in which we still do not have legally binding international instruments. Two important examples are research reactors and fuel cycle facilities. I know that different views exist as to whether a convention is the best solution. But a convention does not necessarily restrict freedom of action with regard to a particular nuclear activity, or force a change of approach or method. Rather, it ensures that we have a uniform standard applicable everywhere with regard to a particular nuclear activity. Our experience with the Convention on Nuclear Safety remains very positive; the first review conference, which reviewed national reports, provided an opportunity for a very constructive dialogue among different countries on how to learn from each other and how to improve the nuclear safety of power reactors. The convention is not really definitive, but uses the concept of ‘obligation de moyens’ — that parties have an obligation to pursue certain means. This is how we can work in the area of safety: we cannot tell you exactly what you have to do, but we can tell you that you need to pursue an overall course of action to attain a uniform standard.

The second direction we have followed is the development of safety standards. Safety standards are very important because they establish a sort of a benchmark for judging whether nuclear safety in a given country is adequate or not, and they are also very important to the application of our safety services, which I will discuss in a moment. The problem with the IAEA’s safety standards was that many of them had become outdated and the overall body of standards was not complete. Particular gaps existed in the areas of the fuel cycle and the disposal of high level waste. During the last five years, the IAEA Secretariat has been working hard, together with the Commission on Safety Standards and various committees, to update our entire corpus of safety standards and to develop standards in the new areas. We expect this work to be completed by 2005.

Another problem with the standards is that, despite the time and effort spent on their development, we do not have indicators to determine whether countries are applying them or in what way they are applying them. About ten years ago we distributed a questionnaire asking countries whether they were applying the standards, but the results were not very conclusive. Again, this is a question for you to look at. International standards are useful only if they are applied. Sometimes we hear that these standards are the “lowest common denominator” — which, again, should not be true. Even if these standards are reached by consensus, they should be of the highest level. They should be standards that countries can apply with confidence, assured that the result will be a strong safety culture.

The third direction relates to the IAEA’s safety services, which we have been operating successfully for a number of years. These services cover many areas of nuclear activity, including the safety of operations, reviews of significant safety events, and reviews of regulatory bodies. I am pleased to see that most of you have made use of one or more of these safety services. As I have often emphasized, these services are not intended to criticize; they are simply there to help. They constitute an international peer review that can identify shortcomings and advise each country on how best to improve the operation of its nuclear facilities. Learning from each other through peer reviews should be a continuous process.

Safety services are provided upon request, but I would like to see more invitations. Many of you also use the World Association of Nuclear Operators (WANO) reviews. While we greatly value WANO’s work, it is an activity among operators — regulators do not receive WANO reports — and that makes a difference.

We are working on two innovations in the area of safety services. The first involves the development — in addition to the issue specific services — of two “integrated safety evaluation” services, the first to cover regulatory bodies, laws and regulations, and the second all nuclear related facilities and radiation sources. On the basis of the integrated safety evaluation, the IAEA would be able to develop country profiles in the area of safety. I believe this would be very useful. Developing this national safety profile would be important — both for us and for you — in helping to identify the priorities to be worked on in the ensuing years. The national safety profile would periodically be updated — say every two years — to see what progress had been made, and what still needed to be done. It is an idea we are still working on, and it is not yet fully developed, but any input you have would be useful.

The second innovation in the area of safety services involves the transfer of safety culture across borders. This could include the exchange of regulators; for example, a Swiss regulator could go to Slovakia to work for a year and through the daily interaction could transfer ‘best practices’. It is in this area in which I would like to see more IAEA engagement, particularly in arranging to send regulators from advanced regulatory systems to some of the developing countries. I believe we can use our technical co-operation programme for some assistance in this area.

This is obviously not an exhaustive list of ideas, but I would like to impress on you that in the area of safety we need to think in an unconventional way. We have many challenges; the conference programme provides only a partial list. Safety performance indicators, which I know you want to discuss, will be helpful for us in conducting our services because we will have a benchmark to work with. The use of safety indicators does not mean that our reviews will become mechanical. This is something we will have to guard against; we must continue to rely on observation, and to improvise when needed. The same is true in the area of verification, where we have specified criteria, but inspectors are advised that reliance on criteria is no substitute for using one's observational skills.

Risk informed decision making is another issue on your agenda. When travelling in different areas, I hear different names — the 'risk informed' approach, the 'prescriptive' approach, the 'deterministic' approach, the 'results based' approach, but I am sure we are all aiming for the same thing — the best way to regulate nuclear activities. The more we have a convergence of views and the more we work together to develop the best approach, the better the result will be for the nuclear industry and for public acceptance.

Regarding the influence of external factors on safety, you all know what is happening. Deregulation, privatization, premature closures of reactors in eastern Europe — all this can obviously have a significant impact on safety. If, for example, a decision is being made to close a facility prematurely, how can we be sure that this will not have an impact on the incentive to maintain a high level of safety until the closure date? When privatization occurs under stiff competition to maximize profits, how can we guard against this having a negative impact on maintaining a high level of safety?

I am pleased that the safety of fuel cycle facilities and research reactors was chosen as a subject for this conference, because, as I said, we do not have conventions in these areas — or even safety standards for fuel cycle facilities. Such facilities are complex, they are not standardized, and we must ensure that safety is addressed in a way that meets the particular requirements of each type of facility. And regarding research reactors, we know that there are over two hundred that have been shut down but not decommissioned. These facilities are obsolete, there is no adequate oversight, there is no updating of equipment and so this area is one that requires renewed focus. From our perspective, we have not been able yet to do much, primarily owing to a lack of resources. In May, a working group on research reactors confirmed that there is a serious safety problem, and noted the lack of a clear policy on the part of governments to improve the situation. Many countries have shut down research reactors, but other priorities take precedence over spending a million or two million dollars on upgrading or decommissioning a research reactor. In many cases, no decommissioning plan exists; in fact, decommissioning itself is a growing problem, not only for research reactors, but also for some of the power reactors that are being shut down.

Maintaining competence in nuclear safety — or maintaining competence in the nuclear industry in general — is also a growing and major issue. Many universities are shutting down nuclear engineering and nuclear physics departments; fewer and fewer young people are moving into the nuclear industry because they feel it is dying — it is no longer a vibrant industry — so they go into information technology, computer science or biotechnology. This is obviously an issue with major safety implications, because regardless of whether we see a future expansion of nuclear power or a freezing of the status quo, we will still need nuclear expertise for at least two to three generations, if only to maintain existing reactors, to deal with decommissioning, and to deal with radiation protection. This means we have a serious problem. Maintaining competence in nuclear safety is only one aspect, because the issue cuts across the full range of nuclear expertise. We have introduced an IAEA programme to examine this problem, to determine what governments are doing, to learn from each other and to understand what the IAEA can do. During a recent trip to Canada, I was told that the Nuclear Safety Commission there is developing a programme to fund chairs at universities, and to offer fellowships. They are using a proactive approach, which takes students with basic training, gives them enhanced nuclear training for six months or a year, and then integrates them into the nuclear sector, giving them a secure tenure.

Many things can be done to make a career in the nuclear industry more attractive. A key factor, of course, is to change the perception of the industry. This requires a two step approach: we need to maintain safety at a high level — making sure that we do not have an accident — and then continue to innovate and develop. As many of you know, much work is in progress on innovative nuclear technology, supported here in the IAEA and outside. We need to keep the nuclear option available. Even if we do not build a new reactor today, every indication is that in the next ten or twenty years we could see a major expansion of the nuclear industry. We must also continue to innovate, and to make sure that the new generation of reactors meets the highest safety standards, as well as meeting high standards for proliferation resistance and economic competitiveness.

In conclusion, let me say that safety policy has implications for the whole nuclear industry, and I wanted to highlight for you some of the issues on which my colleagues and I are particularly focused. I am sure that this conference will address many of these issues, and I very much look forward to your recommendations. By putting our heads together to share perspectives, we will see more clearly how to move forward.

OPENING ADDRESS

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I am delighted to see so many of you here in Vienna for our international conference on Topical Issues in Nuclear Safety. We have an opportunity over the next four days to understand and discuss five topics important to continuing nuclear safety. If we do our job well, I believe we have the right talent here to provide advice and make recommendations for actions on those topics to help shape a sound future for our industry.

We, the participants in this conference, are 235 strong. We are representatives of 53 nations and 5 international organizations, with a variety of individual responsibilities related to nuclear safety, including fuel production, research, regulation, education, human behaviour, science and operations. We represent many different cultures and a diverse set of individual motivations. Our collective wisdom is based upon thousands of years of nuclear safety experience gained over more than four decades of practical experience. Our common ground is, and must remain, a universal commitment to uncompromising nuclear safety.

As a global enterprise, nuclear power has progressed from infancy through adolescence to a potentially robust young adulthood. Performance has been good and, by most measures, is steadily improving. Recognition of the importance of nuclear power in providing the energy needed to advance the global economy and in preserving the global environment is widespread. Reactions to nuclear energy are extremely varied, from continued investment to renewed interest in expansion, to plans for first uses, to opposition and plans to curtail or discontinue its use. It must be our collective will to address the topical issues to be discussed in this conference in a way that achieves continually advancing standards of nuclear safety and safety consciousness. If we do that, we will ensure that these mainly positive reactions continue. In the long run, our work may even help to reverse some of the present day adverse reactions.

In a few minutes we will hear from Mr. C. Packer on the subject of safety culture and safety management. I can think of no more important theme for all of the topics of this conference. Safety consciousness must be integral to all aspects of nuclear energy. Within the confines of a nuclear power plant, a fuel facility or a research facility, it must become the most foundational element guiding human activity and the use of technology. This vitally important topic will be the subject of a full international conference in Rio de Janeiro in December 2002.

As much as we understand our industry, its achievements and the management of its risks, we must also understand that we are a tiny fraction of the interested public. The vast majority of the global population is either uninformed about nuclear energy or holds a view that is fearful either because of the accidents at Three Mile Island and Chernobyl or because the earliest demonstrations of atomic power were destructive. As the Director General has pointed out, nuclear power plants have demonstrated an increase in safety over recent years. Later this morning, Ms K. Daifuku of Foratom will help us to understand the importance of communicating these achievements to the public. We must be mindful though, as we communicate these achievements with deserved pride, that we cannot let either the achievements or the communication of them become a source of complacency that might jeopardize our never ending quest for continuous improvement. At the end of the conference, Ms Daifuku will again help us to communicate the results of this conference when we return home.

For many years the IAEA has been closely involved with the technology of fuel cycle facilities. A review of the scope of the IAEA's safety standards a few years ago revealed that there was no specific guidance on the safety of these facilities. Recent events have underscored the need for such standards. Mr. R. Coates will give us a special introduction to this topic to complement the full topical discussion tomorrow afternoon.

Each of our topical sessions will start with a rapporteur's presentation of the rationale for that particular issue, its present status, the problems identified and issues to be solved, some recommendations for strategic activities and actions for future work and, most importantly, a number of questions to be discussed by this conference. The rapporteur will also provide a summary of contributed papers on the subject. This presentation will be followed by distinguished speakers who will provide us with keynote perspectives and lead-in discussions to trigger discussion on the key issues. Following these presentations, we have a collective obligation for engagement in discussion of the issue. Ideas unspoken will be ideas lost. We all have a stake in all of the topics. I urge your full participation in each session.

In the infancy of the nuclear industry, it was essential to rely on the intuition and understanding of scientists and engineers to determine requirements for the safe design and operation of nuclear facilities. These 'deterministic' requirements and regulations have served and continue to serve us well. Growing experience and maturity have shown, however, that some factors are not as important as once thought and that other factors either not considered before or that were thought unimportant are very important.

Today, advanced analytical techniques and the availability of computing power permit detailed risk analyses on a plant-by-plant basis. In an overall sense these analyses have given us substantially greater knowledge of the factors affecting safety. They are permitting us to use the insights gained to focus resources on the most safety significant issues. On a plant specific basis, the quality of the results is highly dependent on the integrity and depth of the data used in the analysis.

The first of the topical discussions will focus on risk informed decision making. Although risk analysis tools hold great promise to increase safety by ensuring a sharp focus on safety significant issues, we must exercise great care to ensure that the derived data represent truth and the current condition of the facilities analysed. The conference must address important questions regarding the quality, review and use of these analyses and the criteria used in decision making.

Tomorrow we will address two topical issues, the influence of external factors on nuclear safety and the safety of fuel cycle facilities. The first of these topics, the influence of external factors, was raised at the first review meeting of the Contracting Parties of the Convention on Nuclear Safety. It is an issue of global concern and affects not only nuclear power plants but also fuel cycle facilities and research reactors. These factors include market liberalization, political factors, ageing issues, changing regulatory environments, changes in ownership, serious shortages of human experience and talent, and many others.

Some of these factors can pose a major distraction to the operators charged with responsibility for safe operations. Others can lead to a lack of sufficient resources, both human and economic, to provide for the continued safety of operations. Some can disrupt the stability of the regulatory/operations interface. All of these factors are a part of our daily environment. Individually and collectively, they can develop to a point where they have a significant impact on safety focus. We cannot afford to be complacent about them. How will we, representatives of governments, regulatory authorities and operators, know when bold action is required? What can we do? Are there other external conditions or management actions that can provide opportunities to moderate or even turn around factors now understood to be negative?

On Wednesday afternoon we will be pleased to receive advice from a very distinguished panel on one of the most important of the external factors, namely maintaining a competent workforce to design and operate our facilities.

As I mentioned earlier, the IAEA only recently began to address the question of safety standards for fuel cycle facilities. Relatively recent events have indicated that it is an important subject to resolve. Fuel cycle facilities are not reactors. In most cases, their risk profile to the public is dominated by the potential for chemical or other non-nuclear events. Nevertheless, risk associated with criticality or the mishandling of fissile or radioactive material is also present. Ultimately, the source of the risk is unimportant. The potential for damage to life, property and the reputation of the industry is present. Safety standards appropriate to the nature of the facility and the process employed are vitally important. Carefully selected elements of the programmes existing for nuclear power plants and research reactors may be applicable. The topic will be discussed on Tuesday afternoon and we will be asked to help define an efficient approach for developing a variety of activities.

The safety of research reactors is of concern to all of us. Public support for nuclear energy is highly dependent on the continued safety of operation of all nuclear facilities. Some research reactors are very well run, well maintained and benefit from rigorous regulatory oversight. Unfortunately, there are others, both operating and in extended shutdown, with nuclear fuel still present that have weakened operating expertise. Some of these reactors have no regulatory oversight. All of them are subject to ageing degradation and pressures from externalities that also confront other reactors and fuel facilities. This topic will be addressed on Wednesday morning and the conference will be asked to consider actions that might be taken to provide a reasonable assurance of continuing safety. We will also be seeking ideas for the transfer of know-how from the nuclear power community to the research reactor community. All of us should be vitally interested in this issue.

Many of you have enriched this conference with contributed papers, 49 in total that have been compiled in the book which was issued to all of you this morning. Of these, the authors of 26 have indicated that they will present their content as a poster. These papers and posters all contain ideas that may be instrumental in resolving questions posed to the conference. Understanding these ideas can contribute greatly to a sustained high level of safety performance. I urge you to participate fully in the poster session on Wednesday afternoon, before the panel discussion on competence.

On Thursday morning, we will address the subject of safety performance indicators. Much work has been done over the years by individual nuclear power plants, Member States, regulatory authorities and the IAEA. These indicators provide the road-map for management and safety oversight in the application of corrective action to achieve high levels of safety performance. Can a small set of these indicators be used to describe safety culture or the relative risk of individual facilities? Can these indicators be adequately standardized on an international basis to permit benchmarking of performance for management and regulatory action? Can these indicators be used to provide public confidence in the safety of reactor operation? The conference will seek answers and direction for future work on all these questions.

As we address the questions for the conference, we must achieve a broad perspective. In some cases we must make recommendations for actions that must be taken at the level of governments and regulatory or safety authorities. Other actions will be appropriate for operators or for future work on the part of the IAEA. We must not be timid in making our suggestions because we do not have direct control over the decision to adopt the recommendations. Similarly, we should not withhold recommendations because we know that implementation will be difficult. Instead, we should focus on sound recommendations, most likely to resolve the issue.

Finally, on Thursday afternoon before the closing summaries, we will receive two enlightening presentations. The first is on risk management in the chemical industry. Secondly, we will hear about the evaluation of risk from a property insurance perspective. These two presentations are both directly and indirectly relevant to all facilities and should sharpen our approach to their management and oversight.

It is my sincere hope that by the conference closing you will be exhausted. Not only from your days spent in this lovely city but also from intense involvement in and contributions to the work of the conference. At this point, we have a great opportunity before us to shape a bright future for nuclear energy and all its benefits. Let us seize the opportunity and begin the conference.

OPENING ADDRESS

FROM ENDURANCE TO EXCITEMENT — ADVANCING SAFETY AND SAFETY CULTURE

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1. INTRODUCTION

Safety never sleeps. Even as we assemble at this meeting to advance our thinking and to determine our directions, there are thousands of other people operating, planning, maintaining and monitoring the power plants, research reactors, and fuel facilities that are the assets of the industry we work in.

Every design, every plan and every action has the potential to enhance or to degrade safety, and every design, every plan and every action is created by a human being. There is therefore no meaning to nuclear safety without the human dimension. The human being is the common factor, the common link and the common barrier between the hazard and the public. And so we must ask ourselves how effective we are in creating organizations in which it is very difficult to do the wrong thing or to make a mistake.

Just as safety never sleeps, so also safety cannot be isolated from all of our activities. It cannot be managed separately. It is an emergent property of the whole system, including the systems we use for design, the design itself, the management system and the operational habits we adopt.

In the history of our industry there has been a progression of understanding about how we might achieve our safety aspirations. The IAEA has played a key role in promoting the insights that come from shared experience and shared minds. We are here to carry that mission forward over these four days. Each of us who speaks from the platform, each of us who asks a question, each of us who discusses, debates and shares experience in the hallways and in the evenings is contributing. From such exchanges we broaden our insights, we make connections and we see more clearly what part we can play to advance the safe operation of our facilities.

In this presentation I will share with you a model of the key tasks that I believe we must execute to ensure the safety of operational facilities. This model is under review and development as a project of the IAEA. It is a work in progress and your feedback is welcome. I will then make a few remarks on the crucial issue of effective leadership, which is of course the foundation for change.

2. THE MODEL

The model shows ten key tasks that the managers of operating facilities have to execute in order to create a functional system for safety. The model attempts to assemble the fundamental principles into a linked structure. It is portrayed as an overlay in which the background is an adaptation of a conventional business model, superimposed with the ten key tasks for nuclear safety.

I will review the elements of the model very briefly, and let the logic and the linkages speak for themselves. However, I would emphasize that the model is designed to reveal the central importance of linking the human system to the management system and also to the plant systems. You might test its validity by applying it to look for the causes of events, to the process of planning change and to refer to as you listen to other speakers during the sessions.

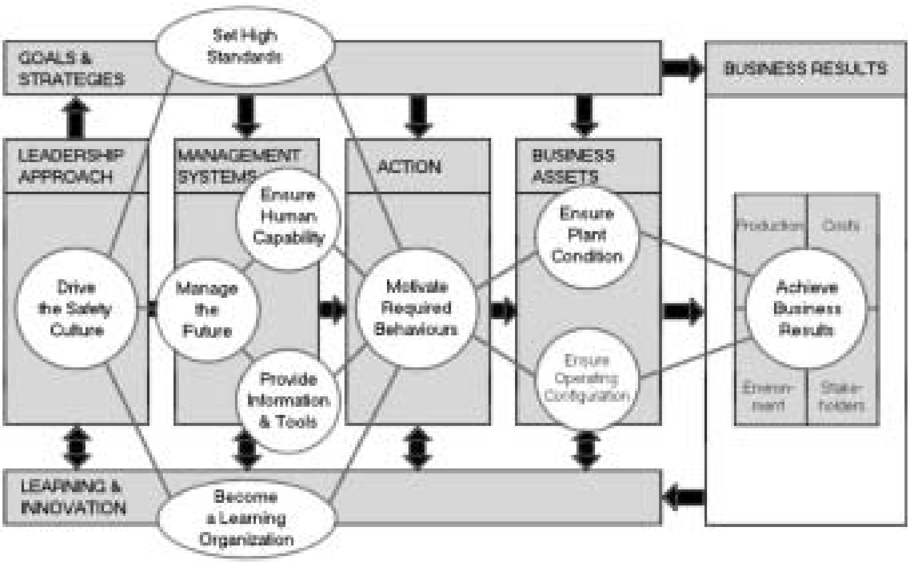

FIG. 1. Ten key nuclear safety tasks.

2.1. Task 1: Drive the safety culture

Shaping the safety culture is the key task of effective leadership. Leaders portray excellence, provide clear direction and create an environment in which people can contribute their best and generate the required results. To build a strong safety culture, the leaders have to shape the underlying assumptions of the organization, and constantly motivate people to move forward and to improve.

2.2. Task 2: Set high standards

Standards and expectations should energize improvement. Senior level managers have to know the standards and consistently take action to hold the organization accountable to meet them. They have to be able to ‘walk, look, listen and fix’ in their organizations based on the standards that are set. This sends a very powerful message if it is done, but an equally powerful and negative message if it is not done.

2.3. Task 3: Manage the future

Safety management is particularly connected with managing overlapping situations and events in the dimension of time. It is necessary in our business to ‘manage every moment’, and we do this by applying three techniques to our activities: we plan, we create procedures and we foster caution and conservative decision making in the face of uncertainty.

2.4. Task 4: Ensure human capability

All of the safety barriers are designed, constructed, strengthened, broken or eroded by people. Therefore, human capability is vital to nuclear safety, and it has to be created and maintained through good planning.

Managers have to ensure that their expectations of people are realistic, taking account of factors such as the innate ability of the individual, skills and knowledge acquired through training and experience, environmental factors that impact on people’s ability to be attentive, careful and deliberate, and also the integrated capability of the whole team.

2.5. Task 5: Provide information and tools

The institutional knowledge, insight and wisdom of an organization are resident in its information and its people. The information includes all of the processes, procedures and reference materials as well as the information technology systems. To a limited degree these can be cross-substituted. For example, more detailed procedures can be created to cater for less skilled staff, but if this is done the people must use and apply the procedures.

2.6. Task 6: Become a learning organization

A learning organization adopts a number of disciplines and practices designed to continually increase its performance and its capability. It is willing to be open and reflective. Without openness (which is fostered by trust), the insights and understandings that might unlock the problems of the organization are not going to be made available to the decision makers.

2.7. Task 7: Motivate required behaviour

Experience shows that human behaviour is the key barrier to major safety events, since human behaviour establishes and maintains the barriers. This is the one element that can break through the layers of defence in depth. The model indicates how everything comes together to influence this issue.

We must also understand that no system of organization is going to produce the required behaviour without individuals exercising personal accountability or responsibility. The concept and practice of accountability is fundamental to all situations, because it links the intent of the organization to the actual performance.

2.8. Task 8: Ensure plant condition

The plant has been designed and analysed to be acceptably safe based on assumptions about its physical-material condition. Therefore, the condition must be known and maintained. In most cases, most of the resources actually applied to the operation of a mature nuclear power plant are directed towards this objective. Inspection and maintenance of the plant, whether on-line or during outages, is the biggest single task.

The overall impact of a number of pieces of equipment being unable to perform their design function cannot be assessed without formal techniques. Methods have been developed to perform this type of analysis and to ensure that we make risk informed decisions.

2.9. Task 9: Ensure operating configuration

The operating configuration must be known and controlled at all times. This task is especially important when work is being performed on the equipment. For example, when multiple pieces of equipment are taken out of service simultaneously for maintenance the overall operating configuration must still support safe operation.

Operation of the plant is the core business of the organization. In a sense, everything else exists to make this possible, easy and safe, and we can capture this idea in the phrase ‘operational focus’.

2.10. Task 10: Achieve business results

The business has to be successful in its objectives, and these objectives are shifting in the face of external factors such as deregulation and early plant closures that are affecting the industry worldwide.

The long term prospects of the organization depend on respecting the stakeholder's interests and expectations. For any organization involved in the nuclear industry this includes an overriding concern for public safety and health, open disclosure of information and conforming with regulations.

3. LEADERSHIP SHIFTS

Having presented an overview of safety management, and perhaps in a way covered 'what we already know', I would now like to move on and talk about the role of leadership.

First, leadership is all about what is possible, not what is certain. The leader's task is to declare possibilities, to make them visible, and ultimately to make them real. It is easy for people in leadership roles to forget this most crucial point.

Second, leadership is about creating an identity for the group. It is the group that performs the tasks, and the leader fosters a strong sense of 'who we are', and reveals the behaviours needed for group coherence and group survival.

And, thirdly, I would say that leadership is more effective if it focuses on what we must learn to do well, rather than what we are doing wrong. In other words it is easier to draw people forward if we show them positive objectives than if we only provide them with negative reflections.

These points (which are only a few of many that we could say about leadership) lead me to pinpoint two specific shifts that I believe we as leaders have to accomplish in order to energize our teams for safety. The shifts relate to the central elements of the model, which are leadership and action.

3.1. Driving safety culture: From endurance to excitement

Leadership catalyses action, and establishes the ideas and the capability on which institutional success is based. Leadership is the key to the 'human system'.

In the early years of our industry we were excited by the technology, by the prospects for the contribution that nuclear energy could make to the world. And then, I think, we entered a period of endurance. Our issues swung from the technical to management. Our leadership energy was focused by some very significant events and performance difficulties, and we collectively recognized the challenges of creating organizations that 'do the right thing, every time'. We have adopted different approaches, but everywhere we are striving to institutionalize good practices and working to improve.

But along the way I think that sometimes we have become weary; sometimes we have lost our excitement and the thrill that comes from overcoming our problems and from innovation. I do not think that we will attract and retain talent in our organizations if we are not exciting. And, as we have recognized, our business is critically dependent upon talent. If we do not move from portraying endurance to portraying excitement we will threaten ourselves with the loss of the best hearts and minds, and that in the long run will turn into a threat to safety.

What should we get excited about? In my experience as a leader and manager I have found that people want three things from their organization:

— They want to work for a cause,
— They want to work for themselves,
— They want to work for a human being.

In principle, we can provide these things in abundance. We have a major contribution to make to world energy and to the global environment. We can provide substantial personal development, and we have lots of capacity to build healthy relationships in our workplaces. In practice, however, we have sometimes fallen back from excitement to endurance. In particular, we need to release our human side.

If we are to build energized organizations we must move from being people who endure to people who are excited. The leaders must declare the possibility of excitement.

3.2. Motivating behaviour: From individualism to identity

People have an immense desire to belong, and to identify with a group that has clear boundaries and clear beliefs. This need for belonging is a tremendous asset when we set out to build high performance organizations. I believe that group behaviour is easier to change than individual behaviour, and that because of this the dominant pull of the group will always hold the key to what really goes on in a workplace. However, many of our management tools as they relate to motivating behaviour are based on the behaviour of the individual (for example, reward systems).

As leaders we therefore need to think carefully about the overall principles by which we motivate our people to do the right things. If we import into our organizations a complete set of tools to manage behaviour, and yet never discuss our vision and assumptions about motivation, we will be importing confusion at the deeper levels of values and beliefs. If we focus our attention on the individual rather than on the group as the unit of behaviour, we are likely to miss the major potential agent for change.

Leaders must therefore take charge of the underlying assumptions that the organization holds about the motivation for human behaviour. This means taking charge of the value system of the organization, and deciding to build a strong identity to which people can relate and belong. This identity has to be founded on a clear set of insights about ‘who we are’, and ‘how we conduct ourselves’. It has to be challenging and exciting.

If we are to move forward in motivating the behaviours required for safety we have to extend our attention from the individual to the group identity of the organization.

4. CONCLUSION

In summary, we have over many years established a powerful body of insight into the effective management of safety. Safety never sleeps and safety is a product of everything we do; it cannot be separated out and managed independently. We must also remember that all of our most serious safety events have had their roots in human error. The concept of ‘safety culture’ was put forward by the IAEA in 1986 to capture these ideas.

The model that has been briefly discussed here illustrates the key tasks that operational management has to perform to advance safety. The key to these tasks is the performance of the ‘human system’, and that depends not only on institutionalized practices, but also on effective leadership.

As we look ahead we face new challenges and we need to bring new people into our industry or we will fail. Our organizations have to compete for talent, just as they compete for results. We will be stronger and safer if we strive to make our organizations exciting rather than simply places of endurance, and if we foster strong organizational identities, rather than simply developing strong individuals.

OPENING ADDRESS

COMMUNICATING NUCLEAR ENERGY TO THE PUBLIC

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It is a great honour for me to speak to you this morning at the opening of this international conference on nuclear safety, and I would like to thank the IAEA for inviting me to address such a prestigious gathering. You will, throughout this week, discuss some very important nuclear safety issues and let me take this opportunity to wish all of you a good and productive meeting. My purpose this morning is to talk about nuclear communications and the safety issue in general terms. I do not plan to be exhaustive and please accept the fact that I cannot cover all aspects of the issues. My presentation will cover:

- Politics — and safety;
- Energy policy — and safety;
- Communications — and safety;
- Recommendations and conclusions.

I will begin by stating what might be obvious — that, among all the entities with a responsibility for communicating on nuclear issues, regulatory bodies must maintain their independence and neutrality and communicate exclusively on the technical and safety side of operations. Regulators should not be involved in either the ethics or politics of nuclear or the business side, such as matters concerning competitiveness.

1. POLITICS — AND SAFETY

Do regulators, and those working on safety, engage in open discussions with politicians? Only rarely, though I should mention that in 2001 I have witnessed two separate occasions in the European Parliament where Judith Melin, the Swedish regulator, and André Lacoste, the French regulator, participated, respectively, in a dinner debate and a committee hearing. In both cases they were very effective and many members of the Parliament appreciated their direct style and 'straight talking'. My sincere wish is that further dialogue could be established between regulators and legislative bodies. The regulators contribute by dispelling many inaccuracies and misconceptions that exist among politicians.

Is it possible for regulators to engage even more? One might argue that they should concentrate on their core business and that communications is just 'the icing on the cake'. Well, if I may use another metaphor, it should not just be 'the tip of the iceberg'. What really strikes me is that we are very good at getting specialists to talk to specialists. We claim to target our audiences, or at least to try to do so. However, we still do not seem to be able to engage in a comfortable dialogue with those who decide our future, namely politicians. Of course, there are those that do not want to be seen talking to the nuclear community because of the fear that it might compromise them and their re-election efforts. I should say, though, that there are some pleasant surprises. I can think of one example (and it is not an isolated one), namely a Danish Member of the European Parliament who has engaged in a rational dialogue with FORATOM and others from the nuclear industry. As you know, Denmark is one of the most anti-nuclear countries in the world, certainly in Europe. So, there is still hope.

Unfortunately, nuclear energy is a highly politicized activity. Recent examples include the closure of Superphénix in France and Barsebäck in Sweden, the German nuclear plant closure agreement, the difficulties with the start-up of the Temelin plant in the Czech Republic, and the political compromise that was reached in Bonn during the climate change negotiations. Here, countries wanted to show the USA their resolve in rescuing the Kyoto Protocol. In the negotiations, the members of the European Union delegation gave in on the issue of carbon 'sinks'. The result was that pro-nuclear countries, such as Canada, Australia and Japan, had to give way on the nuclear clause, one that was proposed by the President of the Conference, Dutch Environment Minister Jan Pronk. The agreement now reads:

> "*To **recognise** that Parties included in Annex I (i.e. industrialised nations) are to **refrain** from using emission reduction units generated from nuclear facilities to meet their commitments under Article 3.1.*"

One could feel a slight sense of desperation, and yet I would like to share with you some optimism — at least in terms of communications. Incidentally, the Kyoto Protocol as it stands still has to be ratified by 55 countries representing 55% of emissions, so we are not 'out of the woods yet'! It will also be interesting to see how this political agreement translates into business terms.

I would like to refer again to the climate change conference, because for the first time nuclear issues had much better and wider coverage than ever before. At previous meetings, and especially in The Hague, many articles had an anti-nuclear bias. However, we were expecting this to happen in the context of an international meeting where there was a strong presence from environmental non-governmental organizations (NGOs). Pressures from them are very great at such events. In contrast, in November 2000 in Bonn, nuclear attracted much more attention and positive coverage than ever before. In addition, major broadcast networks and the print media including BBC television and radio (national and international), CNN, Reuters, Financial Times, Deutsche Welle (German international radio), Associated Press, The New York Times, USA Today, the Australian Broadcasting Corporation, and TV2 Denmark conducted many interviews with members of the nuclear industry. In addition, the coverage given to the nuclear issue by the conference's own daily newspaper was extensive and balanced. This included a very positive editorial, which criticized nuclear opponents for allowing "emotions to get the better of reason". The heading said: "Nuclear power is here to stay!"

2. ENERGY POLICY — AND SAFETY

Certainly, times are changing and our message seems to be getting across. I would now like to illustrate the importance of communications in terms of safety and the shaping of energy policy, with the debate currently taking place in the USA and Europe.

2.1. Nuclear power and the new US energy plan

In May 2001, President Bush outlined a National Energy Policy, "Reliable, Affordable and Environmentally Sound Energy for America's Future". This plan seeks to provide a long term solution to what many in the USA are qualifying as a national energy crisis. This policy recognizes that nuclear has a crucial role to play in meeting the energy needs of the USA. The reason I want to give you some details on the Bush plan is because it covers safety issues.

The policy set five specific national goals, calling on the USA to:

— Increase energy conservation,
— Modernize energy infrastructure,
— Increase energy supplies,
— Accelerate the protection and improvement of the environment, and
— Increase the nation's energy security.

A report produced by the task force projects a significant disparity between energy supply capacity and energy demand over the next two decades. It estimates that if current tends continue, the USA will need between 1300 and 1900 new electricity generating plants to meet this demand.

The report also expressed confidence in the US nuclear industry when it recommended that President Bush should "support the expansion of nuclear energy in the United States as a major component of our national energy policy". It included the following recommendations, four of which were related to safety:

— Encourage the United States Nuclear Regulatory Commission (NRC) to ensure that **safety** and environmental protection are high priorities as they prepare to evaluate and expedite applications for licensing new, advanced technology nuclear reactors.
— Encourage the NRC to facilitate efforts by utilities to expand nuclear energy generation in the USA by uprating existing nuclear plants **safely**.
— Encourage the NRC to relicense existing nuclear plants that meet or exceed **safety** standards.
— Direct the Secretary of Energy and the Administrator of the Environmental Protection Agency to assess the potential of nuclear energy to improve air quality.
— Increase resources as necessary for nuclear **safety** enforcement in light of the potential increase in generation.
— Use the best science to provide a deep geological repository for nuclear waste.
— Support legislation clarifying that qualified funds set aside by plant owners for eventual decommissioning will not be taxed as part of the transaction.
— Support legislation to extend the Price–Anderson Act.[1]

Further recommendations include the need to re-examine policies allowing for the research and use of technologies that reduce the quantities of nuclear waste and plutonium produced. The policy development group also underlined the need for international collaboration to develop reprocessing and fuel treatment technologies that are cleaner, more efficient, less waste intensive and more proliferation-resistant. The full text of the report can be found at *http://www.whitehouse.gov/energy/*.

Thanks to President Bush's initiative, the boost given to the industry is clear. The owners of around one third of the nuclear plants in the USA have notified the NRC of their intention to apply for plant licensing renewals and that the energy policy document leaves the door open for the construction of new power reactor units.

[1] The Price–Anderson Act limits the liability of the nuclear industry in the event of a nuclear accident in the USA. The legislation covers large power reactors as well as small research and test reactors, fuel reprocessing plants and enrichment facilities. It covers incidents that occur through the operation of nuclear plants as well as the transportation and storage of nuclear fuel and radioactive wastes. The act sets up two tiers of insurance. Each utility is required to maintain private coverage at a current level of $200 million per reactor. If claims following an accident exceed that amount, all nuclear operators must pay up to $83.9 million for each reactor they operate. As of August 1998, Price–Anderson capped insurance coverage for any nuclear accident at $9.43 thousand million. This legislation is due to be renewed in 2002 and is currently before the US House of Representatives.

2.2. Europe: The accession question — and safety

We already have some shining examples of East–West co-operation in the nuclear energy field. Plant names like Temelin and Mochovce spring immediately to mind, quite apart from the plant upgrade projects in Central and Eastern Europe that West European companies have been involved in.

It is quite possible that new commercial alliances between companies in European Union (EU) member states and those in the applicant countries could come in for scrutiny from the European Commission — even before the accession process is completed. We have already seen the eyes of Brussels being turned towards Temelin, for instance, for political rather than commercial reasons, due to the unfortunate pressures brought to bear by Austria. It also seems quite likely that the European Commission will be keeping a close watch on any East–West business related linkages that may emerge from among the ranks of the accession countries, as the growth of the EU is now only a matter of time.

As we draw closer to achieving an enlarged EU, we will see the European Commission and the European Parliament taking an increased interest in developments that cross the borders between existing and new member states. This increased interest will cover every aspect of economic activity, including the nuclear power sector.

2.2.1. Harmonization of safety standards

In addition to these commercial and political issues, there may also be renewed calls for EU wide nuclear safety standards to be established. So far, such calls have gone unheeded, but proponents of such standards will no doubt be hoping that EU enlargement will bolster their case.

All this shows that, to some extent, we are entering unknown territory. It is therefore essential for nuclear energy related entities in the new member states to improve their sensitivity to the political messages emanating from the European Parliament in general, and the European Commission in particular.

In Europe, nuclear safety standards are the responsibility of the member states. According to the IAEA, there is no need for specific European safety standards as all EU countries are Member States of the IAEA and have agreed to the IAEA safety standards. These internationally recognized standards are used when comparing safety across national boundaries.

In addition, close co-operation exists. In 1992, operators and regulators consensually set up the European Utility Requirements that are harmonized safety criteria for future light water reactors. The Western European Regulator’s Association (WENRA) was formed to facilitate experience feedback between regulators. However, we are far from a harmonized EU directive on safety. The industry prefers it this way; the regulators prefer it this way. Why fix something that is not broken? The issue has come up lately because of accession issues, since countries that want to joint the EU operate power plants whose safety levels have been put into question. I believe that we are paying a price in terms of communications. May I suggest that if the experts have a strong opinion on these matters, in particular if the current system is preferable, it is so important that the sceptics be convinced and this can only be achieved if they are properly informed and receive accurate information. Certainly regulators have a key role in this area, so I can only encourage you to make your opinions known and your voices heard.

2.2.2. Europe and security of supply

While we can never be complacent about anything, it was encouraging to see that the European Commission's Green Paper on security of energy supply did recognize nuclear energy's advantages in terms of security of energy supply and reducing greenhouse gas emissions. This has placed us in a good position for the debate on the Green Paper that has been conducted since last November.

Such a debate on a European wide level has not taken place in over 20 years. In addition, the initiative of Energy and Transport Commissioner Loyola de Palacio comes at a time when Europe is close to having a fully integrated energy market. The objective is that Europe achieve much greater security of energy supply while meeting its environmental targets. The premise of the Green Paper is that Europe needs a balanced energy mix, one that includes nuclear energy.

Europe has to reconcile the major objectives of economic growth, security of energy supply and environmental protection, bearing in mind its Kyoto Protocol commitments on climate change, enlargement of the EU and geopolitical considerations.

The Green Paper characterizes the government moves in different countries to withdraw from nuclear as a response to the accidents at Three Mile Island and Chernobyl. These political moves are sometimes portrayed as being due to widespread public concerns about nuclear safety. In fact, as we all know, electricity consumers in general care little about how their electricity is produced. Largely, electricity is taken for granted. It is something we only notice when it becomes unavailable. Nuclear acceptance may have taken a dive immediately after Three Mile Island and the Chernobyl disaster, but these can now be looked back upon as isolated aberrations that the nuclear industry learned a great deal from.

So, do nuclear's 'clean air' advantages mean that this energy source can look forward to a renaissance, due to worries about energy crises and climate change? Global warming has become such a hot issue that several journalists have been asking whether these concerns will give nuclear another 'big break'. In addition, several independent experts have publicly advocated the use of nuclear energy in the drive to curb carbon dioxide emissions. They include one of the world's top economists, Lester C. Thurow, and James Lovelock, the British scientist considered to be one of the founding fathers of the Green movement. One of his messages is that if we must have cars, they should be powered by the electricity produced by nuclear plants.

Despite this support, in the near future we will probably not see the sort of 'big break' into the market that the nuclear industry went through in the 1960s and 1970s. What we may see in Europe over the next 20 years is limited 'new-build' in specific countries or regions where there is a clear need for new baseload capacity.

I think what we are experiencing at the moment is the emergence of a growing sense of realism, a feeling that we really do have to get back to basics and think again about how we meet our electricity needs. National or regional government control over electricity production could not be sustained forever, but it did deliver stability and predictability. These are two things that may be lacking in the future, and nuclear power could well be the way to restore them.

These are factors pointing to nuclear as a new investment choice. But what are the conditions necessary to make construction of new nuclear plants a real possibility? **A change to longer term thinking** would be one of them. This relates to the desire for stability that companies and governments may have to develop in the future. **Being unable or unwilling to import electricity** is another condition that would support investment in new nuclear capacity. Imports and exports are an essential part of any free market, but a certain level of self-sufficiency is also needed at both company and national levels. It is worth remembering here that energy independence is a central theme in the Commission's Green Paper on security of energy supply. **Political commitment** is yet another prerequisite for nuclear new-build. This involves having a government committed to:

— energy independence,
— a versatile energy mix,
— reducing greenhouse gas emissions.

Streamlined planning and plant licensing procedures will also have to be in place for power companies to again start taking the road to nuclear. Companies will need to be sure of a final political decision within a reasonable time-frame for them to seriously consider the nuclear power option. This year's debate, based on the Green Paper, will remind everyone of the valuable contribution that nuclear energy makes to improving security of energy supply and enhancing energy independence.

One of the key questions to be raised in the forthcoming discussion will be the issue of radioactive waste. We have the technology and the financing for the construction of deep underground repositories for high level wastes and spent nuclear fuel, and all that is needed now is the political will to build these facilities. This is something politicians must now take into account.

2.2.3. The 6th Euratom Framework Programme on R&D for the period 2002–2006

Let me just mention briefly the European Commission's 6th Framework Programme on R&D. At the end of last year, FORATOM issued a position paper, which made the following key points:

- Priority should be given to waste management, innovative reactor and fuel cycle systems, plant lifetime management, skill maintenance, radiation protection and nuclear safety.
- Community funding should also enhance European nuclear competitiveness and rectify the growing gap between EU research efforts and those in other countries.

In addition, the position paper calls for proposed centres of excellence to be identified in a way that takes into account the efficient translation of fundamental research results into useful products with market potential. Finally, the industry position document makes the point that a substantial increase in the nuclear R&D budget will be needed, if the recommended goals are to be reached.

Enhanced and more focused research work will be an important element of a nuclear revival in Europe. For the European industry to take advantage of a planned resumption of building new reactors, it must be in a fit state to do so — not only physically, but also politically. The main challenges will be communicating with decision makers and the public more effectively.

May I suggest that regulators should and must get involved in this important process. As safety experts, they also have an opinion and strong feelings about what priorities should be established in terms of research programmes and their funding. I feel very positive that the USA is taking the lead with their Generation IV initiative to develop new reactor technologies. However, I would be very disappointed if Europe lost its edge in this area and strongly believe that together, big achievements are in the making.

3. COMMUNICATIONS — AND SAFETY

Whether or not to build new nuclear power plants, make tough decisions on final repositories and decide where to site them are all controversial issues. Putting aside emotions or irrational fears, clearly the acceptance factor is not only dependent on good communication practices but, more importantly, from a collective decision process. In communication terms, there are several possible steps:

- **DAD** = Decide, Announce, Defend,
- **DEAD** = Decide, Educate, Announce, Defend,
- **CASCADE** = Consult, Assess, Suggest, Consult, Amend, Decide, Enact.

Clearly, the ‘CASCADE’ method has proven to be the most effective. It allows the public, not just politicians and the industry, to participate in the decision making process. This way, the responsibility is shared and nuclear energy and spent fuel storage or radwaste disposal are societal issues that have to be tackled by all those who reap the benefits and comforts of having quality, cheap and safe electricity.

3.1. Political and public acceptance

When a doctor communicates with patients about an illness, assuming his or her desire is to be transparent, the following dilemma emerges: to tell the truth — and the whole truth — regardless of unrealistic and raised expectations, or create an environment of anxiety that might prove unnecessary and have negative repercussions. Often, nuclear communicators are faced with similar circumstances. Tell the truth: yes. To go into such technical detail that you end up losing your audience either because of raised fears or boredom: no.

The difficulty is in explaining a highly technical subject and making it understandable for the average citizen. It appears that the industry is much more successful when the target audience lives near a nuclear facility. There are a number of reasons for this. The power plant, its activities and employees are better known within the local community, for instance, and the plant creates jobs as well, so people see the benefits at first hand. Many residents have taken the opportunity to visit the plant and see for themselves, thereby being able to form their own opinions without having to rely on second-hand information.

However, the outreach is difficult because news is normally only of interest when it involves reporting negative developments, and the nuclear energy sector has certainly had its share of biased comment from a small but influential number of journalists.

The continued use of nuclear power in the EU and elsewhere requires an adequate level of public and political acceptance. A lack of acceptance is often mistakenly cited as a reason for the slowdown in nuclear power plant construction in Western Europe and as a justification for abandoning nuclear power.

In fact, the reasons for the slowdown have more to do with the following two factors:

- Plentiful supplies of low priced natural gas, making gas fired power plants a more attractive investment choice;
- More than adequate supplies of electricity which have curbed the need for the construction of new plants of any kind.

In general, moves towards a withdrawal from nuclear in certain European Union countries have been due to party political pressures and have not been a response to public opposition to nuclear. In addition, opinion polls do not show widespread public opposition to the use of nuclear power. Figures consistently indicate that the use of nuclear power does not come high on the list of most people's main worries. Their main concerns focus on other issues such as crime and financial problems. As mentioned earlier, electricity is generally taken for granted in the industrialized world. Electric power only becomes an issue when there is a threat of shortages.

Polls carried out in Germany, Sweden and Finland during 2000 continued to reflect two important factors regarding the public acceptance of nuclear:

— No major opposition,
— Only limited support for a nuclear phase-out.

The German poll showed that well over 60% of the population believe that phasing out nuclear is not a realistic option for the short term. In Sweden, a survey showed strong support for the continued use of nuclear power, with 77% registering opposition to the premature closure of the country's nuclear plants. But only 9% felt that phase-out of nuclear power production is of most importance. An overwhelming majority considered it important to take into account the fact that nuclear plants emit virtually no greenhouse gases.

In France, according to a poll carried out in April 2001, 88% believe the ill effects of greenhouse gas emissions should be taken into account when making energy generation choices. And 67% of the persons polled believe that nuclear is an important factor for France's security of supply.

In Finland, plans for a new reactor unit have been under serious consideration, and a poll last year showed the significant level of trust placed in the country's nuclear industry. Just over two thirds of those polled believed Finnish nuclear power was "not risk-bearing". However, Finns appear to be split 50–50 regarding the construction of a new nuclear unit.

In another example, recent polls in June 2001 in the Czech Republic show that, despite the very strong anti-nuclear movement in Austria, 69% of Czech citizens continue to support the completion of the Temelin nuclear power plant.

The level of public acceptance in the USA appears to be quite high. Opinion surveys have thrown up the following findings:

— The number of Americans who favour the use of nuclear energy is higher now than at any time since 1983. Recent surveys show that information about the 'clean air' benefits of nuclear energy increases favourable attitudes.
— In a poll conducted in April 2001, 66% agreed that the USA should definitely build more nuclear power plants in the future, compared with 51% in January 2001 and 42% in October 1999. Support for extending the operating licences of

the 103 reactor units in the USA remained strong at 81%. And 68% said nuclear energy should play an important role in meeting America's future energy needs.[2]

Overall, and certainly in some West European countries, there seems to be little connection between the level of public acceptance and the policies being pursued by some individual governments. It could be concluded, therefore, that the real obstacle to the further development of nuclear power is political opposition, rather than negative public attitudes.

Political opposition can be traced back to the accidents at Three Mile Island and Chernobyl, as mentioned earlier. Support for nuclear is reported to have diminished in Japan after a series of incidents, notably the sodium coolant leak at the Monju prototype fast reactor. In contrast, the accident at the Tokaimura uranium conversion plant in September 1999 does seem to have had a lasting impact on Japanese public opinion, yet it has not changed the Government's resolve to expand Japan's nuclear generating capacity.

Experience shows that lapses in safety do have a clear negative impact on public acceptance and the level of political support. Three Mile Island made the legislative and regulatory environment much more difficult for nuclear in the USA, and the Chernobyl accident caused countries like Germany, Sweden and Italy to reconsider the nuclear energy option.

While there is no room for complacency on the safety front, it is difficult to pin down how public concerns become translated into changes in political policy. Clearly, a major accident on the scale of the 1986 Chernobyl disaster would have a devastating effect on public attitudes towards nuclear.

There are no easy answers to gaining and maintaining public acceptance. As I have tried to show, the prevailing socio-political conditions are different from one country to another.

3.2. Nuclear safety and communications

Last June, the IAEA held a meeting bringing together nuclear communications professionals to exchange views on "Nuclear Perspectives for Public Communication". Let me share with you some of the conclusions:

- More needs to be done to raise public awareness;
- More research is needed to better assess public attitudes towards nuclear energy;
- Communicators should promote awareness of risk perception and risk management, high safety standards, national regulatory regimes and international nuclear safety programmes;

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[2] *Source*: Nuclear Energy Institute, 23 January 2001.

— Nuclear power plant operators and regulators should do everything possible to ensure that the risk of an incident or accident is remote in the extreme;
— All players, including regulators, have the responsibility to build and maintain public trust;
— In addition to their principal role, regulators have to inform the public about plant problems that might have an impact on public health or a negative impact on the environment;
— Regulators should rely exclusively on factual information and avoid messages that might be construed as promoting nuclear energy;
— Regulators and plant operators should be prepared to place both positive and negative information in the public domain;
— Greater efforts should be made to have nuclear energy related topics covered in schools, colleges and universities;
— Both regulators and operators should target their audiences and adapt their messages accordingly;
— The public should have a more proactive role in the evolution of regulatory policies and practices.

4. RECOMMENDATIONS AND CONCLUSIONS

I can only say that I fully support the recommendations of my colleagues. Let me share my perspective not only as a communications professional but also as an observer, and may I go even further. Being very conscious of the separate roles of the different players in the nuclear sector, would it not be possible to encourage a more proactive approach by all in terms of communications, including the regulators? By this I mean correcting mistakes made by industry of course, but also those errors made in the press and by politicians, in order to make sure that the true story is known. May I suggest that if a regulatory body says nothing regarding the premature, **politically motivated** closure of a plant, then the authority itself is bowing to the same political pressures that are imposed on the operating organization. It is worth recalling here that the regulator has a duty to act independently, to concentrate on nuclear safety issues and not to be influenced by outside pressures, be they commercial, political or ethical

Allow me to be provocative. Let me go so far as to say that in my view the system of having political appointees as regulators really jeopardizes the system. In some countries, safety policies are carried out to please politicians and ensure their re-election rather than for genuine safety reasons. No other industry is manipulated in such a way. If you recall, at the beginning of my presentation, I mentioned that “regulatory bodies must maintain their independence and neutrality and communicate mainly on the technical side of operations”. May I suggest that this independence and neutrality apply to all sectors, including politicians.

We all agree that nuclear communications work is fundamentally about information and education. It is about combating the ‘fear of the unknown’, while remembering the famous quote: “We have nothing to fear but fear itself.” Let me just reinforce one point. I am a strong believer that more should be done in schools, that the basics about radiation and nuclear energy should be taught in all schools, not just in those near a nuclear power plant. We need to invest in our future and that includes explaining to the next generation what its choices are and what the advantages are of different energy sources. For this huge task, there is room for everyone, as I believe that educators can come from different sections of society and can wear different hats. I leave you to reflect on these recommendations and wish you continued success in your work.

Thank you for your attention.

OPENING ADDRESS

SAFETY IN THE NUCLEAR FUEL CYCLE INDUSTRY

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1. INTRODUCTION

The nuclear fuel cycle consists of a broad range of nuclear installations employing a wide variety of technologies to harness the power of the atom. Nuclear fuel cycle facilities encompass mining and milling, conversion to uranium hexafluoride, enrichment, fuel fabrication (including mixed oxide (MOX) fuel), reactor operation, spent fuel storage, reprocessing, vitrification, waste management and storage, and finally waste disposal. The transport of nuclear material is also an integral part of the fuel cycle, and operations such as isotope production (e.g. sealed sources) are closely allied activities.

Several parts of the fuel cycle have been subject to detailed consideration by standards setting organizations such as the IAEA. In particular, the design and operation of nuclear power plants and research reactors, which are the most widespread nuclear facilities, are covered by a wide range of published IAEA safety standards and guidance material. In addition, associations of power plant operators such as the Institute of Nuclear Power Operations (INPO) and the World Association of Nuclear Operators (WANO) have established respected operational standards and peer review systems. Transport activities are addressed by authoritative IAEA standards which are the basis of national legislation in many countries. Waste management and disposal activities are also currently addressed by IAEA safety documentation, and indeed the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management has recently come into force.

The other components of the nuclear fuel cycle have not been addressed as comprehensively within the international safety arena, nor indeed within industry based organizations, although the OECD Nuclear Energy Agency (OECD NEA) has published an overview of safety in the nuclear fuel cycle [1]. The safety of mining operations brings into play somewhat specialized considerations which are best addressed separately. Hence this review concentrates on the safety of nuclear fuel cycle facilities covering milling, conversion, enrichment, uranium fuel fabrication,

TABLE I. NUMBER AND TYPE OF FUEL CYCLE FACILITIES

Facility type	Total	Developing States	Currently operational
Milling	189	77	58
Conversion	45	11	31
Enrichment	39	14	22
Fuel fabrication	72	19	49
Interim storage	99	16	67
Reprocessing	38	9	13
MOX fuel fabrication	22	1	10
Total	504	147	250

interim used fuel storage, reprocessing and MOX fuel fabrication, together with associated waste management.

The IAEA maintains a database of fuel cycle facilities in its Member States in the Nuclear Fuel Cycle Information System (NUFCIS) [2]. Table I presents summary data listed by facility type and operating status. Of the 500 listed facilities, about half are reported to be currently operating. About one third of all facilities are located in developing States.

There is an extremely wide range of technologies employed across fuel cycle facilities, ranging from relatively conventional ore handling plants, through more sophisticated mechanical handling to very complex chemical plants with extensive shielding, containment and remote handling capability. The size of the fuel cycle plants and complexes also varies widely, with facility employment numbers ranging from several tens of workers up to many thousands of employees. This range presents significant challenges in terms of developing a consistent set of useful and valid safety guidance material, and indeed ensuring that relevant safety information on international developments and guidance is available where it is most useful.

2. KEY UNDERPINNING ISSUES IN FUEL CYCLE CO-OPERATION

There are perhaps two key issues which have had a strong influence on the development of international exchanges on the safety of fuel cycle facilities — the military dimension and commercial competition pressures.

2.1. The military dimension and the historic legacy

The original development of fuel cycle technologies and facilities was, in most cases, linked to the production of nuclear weapons. Key technologies such as enrichment and reprocessing were initially focused on the production of military material. Particularly in the Cold War climate, the ethos was inevitably strongly biased against the sharing of information which could be considered as advantageous to another party. Such sensitivity inevitably extended to safety related issues, not because it was inappropriate to share safety learning per se, but because of the concern that such information (e.g. on incidents, events and safety experiences) would intrinsically aid interpretation of the technologies employed and the process materials used, etc., which was inappropriate for a wider audience.

These sensitivities are still present in some aspects of today's environment, although to a much lesser extent. Nonetheless, they must be factored in and recognized with regard to any arrangements to promote international co-operation in this field.

The military dimension also gave rise to another factor that exerts a considerable influence over current day considerations. The early military facilities were developed under intense political pressure to deliver weapons according to the shortest possible time-scale. A combination of this factor and the consequences of an inherent lack of underpinning knowledge in newly developing scientific and technical fields meant that facilities were designed and constructed to fewer stringent radiological standards and without any consideration given to decommissioning requirements. Additionally, the facilities were operated without adequate attention, as judged from today's perspective, given to the treatment of the wastes arising — in general such wastes were placed in basic storage facilities that were generally adequate for medium term storage, but without any waste conditioning, and again without great consideration of their retrievability. These represent some of our oldest nuclear facilities, now several decades old.

These historic facilities and wastes therefore present a specific and unique challenge in ensuring that they are dealt with safely and in a timely manner. This challenge is over and above the safety issues relating to operational fuel cycle facilities, which are addressed later in this paper. The challenge is compounded by the realization that, because of the technical difficulty of the clean-up work, including in many cases a lack of adequate detailed knowledge of the design and construction of the facilities and the composition of the wastes, the cost of dealing with these historical issues to modern day standards is extremely large. The funding of such work from national government resources can be the limiting step in moving forward with full programmes for recovery and remediation. The safety community must respond with the identification of key priorities and a logical and orderly programme that will deliver timely improvements towards the ultimate safety objectives in line with the funding capacity.

2.2. Commercial competition

Commercial considerations also give a different dimension to the sharing of safety information for fuel cycle facilities compared to nuclear power plants.

Suppliers of uranium ore concentrates, enrichment services, fuel manufacture and spent fuel management services are operating in a global market that is increasingly competitive. Utility customers are coming under greater cost pressure and are becoming less tied to historic suppliers, and service providers are improving their ability to supply an ever-wider range of services. Within this competitive world, suppliers will continually seek competitive advantage. This could encompass increased knowledge of competitors' operations and/or the use of safety and environmental performance data as market differentiators. Both of these factors militate to some extent against the sharing of safety information.

This contrasts with the nuclear power plant picture, where market competition is generally between nuclear electricity and other forms of electricity generation. For example, a nuclear power plant on the West Coast of the USA is not competing with an East Coast nuclear plant or one located in France or Japan. Hence the mutual interest in improving safety standards through co-operation and sharing does not have the same degree of counterbalancing considerations of competition.

While competition may discourage the sharing of safety information between nuclear fuel cycle facility operators, it is nonetheless clear that there are other strong factors working in the other direction to encourage the sharing of such information. Perhaps the most important of these is the reverse of the global market — the recognition that events or incidents anywhere in the world will influence the climate of public opinion in all countries. It is just such considerations which led to the establishment of co-operation between nuclear power plant operators with the objective of driving up standards across the reactor operating community. INPO was established in the USA in the wake of the Three Mile Island incident and WANO was initiated following the Chernobyl accident. As yet, formal co-operation between fuel cycle operators has developed much more slowly, perhaps in the light of the factors discussed above. However, the JCO fuel fabrication facility criticality accident in Tokaimura, Japan, in 1999 has revitalized such considerations and has led to discussions to secure a more formal basis for safety co-operation, particularly in the fuel fabrication arena. The International Network for Safety Assurance of Fuel Cycle Industries (INSAF) has now been established to facilitate the exchange of safety information and the sharing of best practices.

3. FUEL CYCLE SAFETY — COMPARISON WITH NUCLEAR POWER PLANTS

3.1. Similarities

Over a number of years the IAEA has developed a comprehensive set of safety series documents which address, in a structured manner, the safety of nuclear installations. The Safety Fundamentals publication, ‘The Safety of Nuclear Installations’ [3], presents an international consensus on the basic concepts underlying the principles for the regulation, design and operation of nuclear installations. This is equally applicable to fuel cycle facilities and nuclear reactors, as are other top tier standards documents such as the IAEA International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [4] and documents of the International Nuclear Safety Advisory Group (INSAG). However, more detailed requirements and guides within the IAEA family are more closely focused around specific types of plants, such as nuclear reactors, and in many cases are not directly applicable to fuel cycle facilities.

Similarities across the whole field of nuclear plant operation are also evident. INPO has published an extensive set of ‘Performance Objectives and Criteria for Operating Nuclear Electric Generating Stations’ [5], based on wide experience of nuclear power plant operations. All 39 identified Performance Objectives are directly applicable to fuel cycle facility operation, as are the overwhelming majority of the supporting detailed criteria. In cases where they are not directly applicable, analogous criteria can be readily identified.

Another key aspect common to the identification of appropriate safety standards for all nuclear installations is the interaction between risk perception and public acceptance. Increasingly, across the complete fuel cycle the relevance and importance of securing a greater level of public acceptance is recognized as an essential basis for the future of the industry. Inevitably this is leading to greater openness on the part of public authorities and industrial organizations, and to an acceptance of public involvement in the standard setting process. This move does not differentiate between the different facilities in the entire fuel cycle.

3.2. Differences

Fuel cycle facilities differ from reactors in several important respects:

- By the very nature of fuel cycle facilities, nuclear/radioactive material is widely distributed throughout the process, often in the form of liquids and powders which are potentially very mobile. This contrasts with reactors, where the majority of material is contained within fuel elements in the reactor or fuel storage areas. Fuel cycle facilities therefore present different challenges in terms of containment and ventilation.
- Fuel cycle facilities have a much greater reliance for safety on operator performance and administrative controls. While design philosophy still requires the greatest possible emphasis on the provision of engineered safety features, the extent to which this can be achieved is limited by the practical need for human intervention in many parts of the process. This relatively high level of

'human–machine interface' therefore requires great attention to human factors considerations.

- Experience has shown that there is a higher level of modifications, intervention and active maintenance for fuel cycle facilities than for reactors. As with other aspects mentioned above, this puts greater emphasis on the adequacy of work management arrangements, in addition to the importance of securing an appropriate initial design philosophy and provision.
- A combination of mobile concentrations of nuclear material and significant operator intervention leads to the requirement to have a strong emphasis on criticality control. A recent conference [6] reported about 20 known criticality accidents in fuel cycle plants, the most recent in JCO (Japan) in 1999. Again, a combination of basic design provisions, work management and safety culture are the key controls in addressing this vitally important hazard.
- Fuel cycle facilities may also pose hazards due to releases of chemically toxic and corrosive materials. Key materials used include hydrogen fluoride, organic solvents and acids. As well as being hazards in their own right, there is the potential for the generation of chemical energy to act as the driving force for the release of radioactive materials.
- Fire is a potential hazard, especially where some organic solvents and/or oxidizing chemicals are utilized.
- In general terms, fuel cycle facilities do not have the same combination of high stored energy (heat and pressure) and high inventory when compared to reactors. This results in generally smaller maximum credible accidents and more slowly developing accident scenarios. However, criticality events and chemical reaction incidents can develop rapidly, with locally serious consequences.
- There is a strong interdependence between the facilities that comprise the fuel cycle. The products of one facility become the feed material for other facilities and processes later in the cycle. Hence issues which interfere with the efficient operation of the downstream plants can create backlogs and associated safety issues in upstream facilitates.
- Because of the more dispersed and mobile nature of radioactive material in fuel cycle plants, waste management issues become more challenging. This encompasses discharges to air and water as well as solid waste arisings. The magnitude and nature of wastes arising vary significantly according to the type of facility. At the back end of the fuel cycle, issues related to the management and treatment of the longer lived fission products such as ^{14}C and ^{129}I become significant.
- Decommissioning strategies raise different issues for fuel cycle plants because of the extensive and dispersed nature of process radioactive materials. This necessitates great emphasis on an effective post-operational clean-out of process material at the end of the operational life of the facility. As with

reactors, there is usually some advantage in waiting some time to allow for radioactive decay before commencing full decommissioning. However, this strategy does not apply in general to plutonium facilities, where in-growth of ^{241}Am will lead to increasing levels of radiation with time. In addition to the above considerations, further decommissioning challenges relate to some older facilities as outlined in Section 2.1 above.

— Many of the above factors conspire to result in the safety cases for fuel cycle facilities being more varied and less consistent across the various types of plants than is the case for reactors. While the overall level of hazard is often lower than for reactors, the basis of the safety case may be more reliant on a wider ‘basket’ of measures and protective mechanisms.

4. OPERATIONAL EXPERIENCE

As with all nuclear and other industrial facilities, over the course of time there have been accidents and events within fuel cycle facilities which have resulted in acute safety consequences and releases of radioactive materials to the environment. In addition, as indicated earlier, the early fuel cycle plants are presenting significant legacy challenges in terms of decommissioning, waste management and cost. However, the scale of the safety issues presented by nuclear fuel cycle plants is in broad terms not significantly different from that relating to other nuclear plants and wider industrial activity.

There are many examples of the consistent safe operation of nuclear fuel cycle facilities. For example, within British Nuclear Fuels’ UK fuel cycle operations (principally fuel fabrication, reprocessing and legacy waste management/decommissioning), the key safety indicators demonstrate that:

— The rate of safety incidents (International Nuclear Event Scale (INES) Level 1 and above), normalized to the scale of nuclear operations on the sites, has decreased by a factor of about 2 over the last decade.
— The average worker dose has decreased by a factor of 4 over the last 15 years to the current level of about 1 mSv per annum.
— The number of workers exposed to radiation levels greater than 10 mSv has decreased from 1800 to about 15 over this period.
— Discharges of the principal radionuclides to the sea are less than 1% of the peak levels.

Such improvements are evident across many other fuel cycle plants in other parts of the world.

5. SUMMARY AND CONCLUSIONS

Nuclear fuel cycle facilities are widely distributed throughout the world, both in developed and developing States. There is a wide range of types of facilities, of technologies employed and in the magnitude of employment within such facilities. Despite these differences the top tier fundamental safety principles developed by organizations such as the IAEA are applicable across the full range of nuclear facilities, and indeed the principles of good operational management developed by INPO in the context of nuclear power plants are in general equally valid for fuel cycle facilities.

However, there are some key differences in safety management between reactors and fuel cycle plants. Some of these have been rooted in the early military origins of many fuel cycle plants and technologies; some others are linked to the current commercial dimensions of the global market place. Many of the technical safety differences stem from the inherent wide distribution of radioactive/nuclear materials throughout fuel cycle plants, often in a relatively mobile physical form, together with a greater level of human intervention within the processes.

Any further development of safety standards, associated guidance or operational support and review systems must take account of these underpinning factors which influence the management of safety in fuel cycle plants, together with a recognition of the identified differences from the somewhat more uniform world of nuclear reactors.

REFERENCES

[1] OECD NUCLEAR ENERGY AGENCY, The Safety of the Nuclear Fuel Cycle, OECD, Paris (1993).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, The Nuclear Fuel Cycle Information System, A Directory of Nuclear Fuel Cycle Facilities, IAEA, Vienna (1996).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, The Safety of Nuclear Installations, Safety Series No. 110, IAEA, Vienna (1993).

[4] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[5] INSTITUTE FOR NUCLEAR POWER OPERATIONS, Performance Objectives and Criteria for Operating Nuclear Electric Generating Stations, Rep. INPO 97-002, INPO, Atlanta (September 1997).

[6] A Brief History of Criticality, Background No. 11/99/A, NUCNET (October 1999).

Topical Issue No. 1

RISK INFORMED DECISION MAKING

(Session 1)

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Topical Issue Paper No. 1

RISK INFORMED DECISION MAKING

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1. RATIONALE

To date, probabilistic safety assessments (PSAs) have been performed for more than 200 nuclear power plants (NPPs) worldwide and are under various stages of development for most of the remaining NPPs. The state-of-the-art is to have a full scope Level 2 PSA (including external events and low power and shutdown) which is maintained as a 'living PSA' with regular updating. Modern computer technology allows frequent recalculations of the PSA to evaluate the impact of changes in operation or design and allows use of the PSA in the form of safety or risk monitors. There is a general agreement, as documented in various IAEA Safety Standards, that the deterministic approach to nuclear safety should be complemented by a probabilistic approach.

Though PSAs have been used extensively in the past, their use was usually limited to a variety of applications on a case by case basis as deemed necessary or useful. There is now a recent development, led by the USA and followed by several other countries, to move to a much expanded use of PSA in what is termed 'risk informed decision making'. The main driving force behind this movement is the expectation that the use of risk insights can result in both improved safety and a reduction in unnecessary regulatory requirements, hence leading to a more efficient use of resources for NPP operators and the regulatory authority.

One of the key challenges in truly risk informed decision making is the reconciliation of PSA results and insights with traditional deterministic analysis. This is particularly true when it comes to defence in depth and safety margins. PSA results often conflict with deterministic insights. If a method of reconciling these conflicts is not defined, then risk informed can become deterministic plus PSA. This results in PSAs being an additional layer of requirements rather than a tool for optimized decision making. Alternatively, if PSA information is always used to override deterministic considerations, then that is a 'risk based' approach, not a risk informed one.

This issue is less important if the plant is being upgraded (e.g. risk informed design improvements). However, when optimization of requirements (e.g. relaxation of regulations) is being pursued, it becomes a central issue. Table I demonstrates the complementary nature of deterministic and probabilistic approaches to safety evaluation.

A prerequisite for such an expanded use is the availability of a high quality 'living PSA' which supports the various applications. The PSA quality should be commensurate with its intended application. This means that there is not one standard for judging the adequacy of the PSA, but that the quality of the PSA should be judged in relation to each specific use or application. Many efforts have been devoted to achieving consistency and quality of PSAs. They include peer reviews (e.g. the

TABLE I. STRENGTHS AND LIMITATIONS OF DETERMINISTIC AND PROBABILISTIC APPROACHES TO SAFETY

	Deterministic approach	Probabilistic approach
Strengths	— Underlying principles of defence in depth, redundancy and diversity provide technically sound design criteria. — Responsible for outstanding safety record. — Resulting requirements expressed in pass/fail rules and are straightforward to implement and to verify compliance. — Safety margins developed for structures, systems and components provide protection for a range of accident challenges beyond the design basis.·	— Inclusive treatment of any accident scenario that potentially contributes to risk; not confined to design basis accidents. — Accident frequencies and consequences dealt with quantitatively based on realistic assumptions. — Facilitates ranking of technical issues and events based on contribution to risk. — Quantitative approach to evaluating impacts of uncertainties on risk estimates. — Provides a consistent way to feed back operating experience to refine risk predictions.
Limitations	— Limited to somewhat arbitrarily defined design basis accidents and single failure criterion (or N-2 rule); protection for beyond design basis accidents only implicitly provided. — Assessment that decisions create no undue risk to the public made on a qualitative and subjective basis. — Deals with a limited set of uncertainties by use of conservative assumptions and safety margins; many uncertainties not explicitly addressed. Combination of conservative assumptions tends to obscure understanding of realistic behaviour. — Apart from need to demonstrate that such accidents are incredible, provides no explicit assessment of the capabilities to protect against beyond design basis accidents which dominate the public risk.	— Results highly dependent on and limited by state of knowledge; subject to change as knowledge evolves. — Use of conservatism skews results; realistic treatment not always feasible. — Requires robust and complete risk model and identification of all sources of dependence to avoid optimistic results. — Uncertainties in risk estimates may be too large to support certain decisions. — Limited to accidents caused by randomly occurring failures; requires assumed validity of the deterministic basis of the plant. — Human actions, treatment very difficult, and no viable approach to errors of commission.

IAEA's IPERS/IPSART programme)[1], PSA standardization efforts (e.g. United States Nuclear Regulatory Commission (NRC) PRA Procedures Guide, IAEA PSA Guidelines, the recent draft American Society of Mechanical Engineers (ASME) PSA Standard, IAEA–OECD NEA guidance for regulatory review of PSAs) and compilation and comparisons of PSAs for similar types of NPPs, including comparisons of the success criteria and failure rates used. Another concept being pursued is to provide a quality grading of the major PSA elements and subelements required to support a specific application and to assess the quality of the PSA in these required areas.

This paper draws on some information compiled in IAEA-TECDOC-1200, Applications of Probabilistic Safety Assessment (PSA) for Nuclear Power Plants [1]. This document has been drafted as a result of several meetings, and the IAEA would like to gratefully acknowledge the participation of all the experts who contributed to the draft. Ms A. Gomez Cobo was the officer responsible for that document.

1.1. BACKGROUND

Historically, PSAs have primarily been performed by regulatory bodies, who have used them to gain generic risk insights (e.g. WASH-1400 [2] and NUREG 1150 [3]), or by licensees, who have used them for a variety of purposes, including compliance with regulatory requests to support a safety case, identification and understanding of key plant vulnerabilities, and analysis of the impact of proposed design or operational changes. PSAs have also been used to evaluate the design of new plants. Having invested considerable resources in developing PSAs, there is a desire on the part of both licensees and regulators to use the insights derived from them to enhance plant safety, while operating the nuclear stations in the most efficient manner. PSA is an effective tool for this purpose as it assists in targeting resources where the largest benefit to plant safety can be obtained.

An NPP PSA, in principle, has the potential to provide an understanding of the inherent risk of operating the plant over a much wider range of conditions than traditional deterministic methods, which generally define what is assumed to be a bounding set of fault conditions. Furthermore, the adoption of conservative assumptions relating to plant and system performance is an accepted approach to addressing uncertainty when performing these deterministic analyses. By using PSA, which considers a much wider range of faults, takes an integrated look at the plant as a whole (system interdependences), uses realistic criteria for the performance of the plant and systems and tries to quantify the uncertainties, more 'risk informed' decisions can be

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[1] **IPERS:** International Peer Review Service; **IPSART:** International Probabilistic Safety Assessment Review Team.

made. The PSA, therefore, is useful to improve plant safety and safety management.

However, while the PSA can be seen, in principle, to provide a broader perspective on safety issues than deterministic approaches, the application of sound engineering principles has been demonstrably successful in achieving a high level of safety. Besides, while PSA is a useful tool to improve plant safety, its weaknesses and limitations also need to be acknowledged.

1.2. PSA IN DECISION MAKING

The extent to which PSA results can contribute to a decision is dependent on the level of detail of the PSA model, its quality, its completeness, and on whether the subject of the decision is amenable to analysis using a PSA. For certain specific and limited applications, a relatively simple PSA model may be adequate. However, for other applications, such as when a PSA is to be used as a day to day tool for decision making at NPPs, all aspects of the model are brought into play, and a detailed, comprehensive model is necessary. As the understanding of plant performance improves, and the weaknesses, limitations and technical difficulties associated with the PSA are progressively remedied, the quality and usefulness of the PSA will increase.

The extent to which Member States are making use of PSAs in decision making varies greatly. Not all countries have a regulatory framework in place for the use of the probabilistic approach. Most countries use PSAs in the design area to support NPP upgrading, backfitting and plant modifications. Also, for new NPP developments, PSA has become a standard tool in design. Recently, emphasis has been given to the use of PSA in determining the safety classification of systems and components. There is a large potential for use of PSA in the operational safety area, in particular regarding the optimization of technical specifications, configuration control during maintenance and determination of test intervals [4]. However, more extensive use in this area is limited by the quality of the available PSAs in some countries to support such applications.

The opinions of a number of specialists and users have been collected at a recent meeting. They indicate the following broad prioritization in terms of the present usefulness of the application to risk management. Though it is noted that this prioritization could well be different for a specific plant, Table II may nevertheless provide useful indications to those managing resources. In addition to the areas of applications listed, risk informed prioritization of regulatory inspection is recently being explored in several countries.

Whatever the level of detail adopted, the model must reflect the current status of the plant. Therefore, if the PSA is to be of continuing use in the enhancement and understanding of plant safety, it must be updated or modified when necessary to reflect changes to the plant and its operating practices, and also to reflect improve-

TABLE II. PRIORITIES FOR PSA APPLICATIONS

Application	Priority
Use of PSA to support NPP design	High
Use of PSA to support NPP upgrade and back-fitting	High
Use of PSA to evaluate safety issues	High
Use of PSA to improve operator training programmes	High
PSA based evaluation and rating of operational events	High
Use of PSA to improve emergency operating procedures	Medium
Use of PSA to support accident management	Medium
Risk based configuration control	Medium
Use of PSA to support NPP periodic safety review	Medium[a]
Use of PSA in maintenance	Medium
Use of PSA in connection with technical specifications	Medium
Use of PSA to support emergency planning	Low
Risk based safety indicator	Low
Graded QA	Low

[a] Although this application has appeared overall as being of medium priority, it was clear that the usefulness of PSA within the periodic safety review (PSR) process is very much dependent on the degree to which PSA has previously been applied to the NPP in question.

ments in methods. This has led to the concept of ‘living PSA’ (LPSA). Thus, a PSA used to support decision making must have a credible and defensible basis, and must reflect the design and operation of the plant. Also, it is very important that the PSA be accepted by the plant and the regulator. Therefore, all those facets of PSA quality that are independent from the intended applications, such as traceability, consistency, documentation and quality assurance, are very important aspects that need to be considered when developing a PSA and afterwards when using it for different applications. Some of the applications can be performed in advance of initiating changes at the plant, some applications require on-line use. Acceptance of the PSA by the plant is enhanced by the significant involvement of plant staff in its development. Acceptance of the PSA by the regulator is enhanced through a clearly defined review process and established procedures for using the results in practice.

One criticism often levelled at PSAs which, for many people, limits their usefulness, is the uncertainty within the PSA community of how to address some of the modelling elements. Typically, such uncertainties are addressed by making particular assumptions or adopting a specific model for an element of the PSA. There are ongoing efforts to improve the accuracy and to standardize or at least harmonize PSA and PSA applications. However, rather than being an impediment to using PSA, this identification of uncertainties can be turned into a strength. An understanding of the impact of these uncertainties on the PSA results, obtained, for example, by performing sensitivity analyses, can lead to more robust decisions. This understanding is dependent on the sources of information used to develop the PSA model and the adequacy with which the information is documented. Therefore, in order to achieve this goal, a comprehensive documentation of the PSA is necessary, including identification and specification of the underlying assumptions. Consideration of weaknesses and limitations must of course also be taken into account in the traditional deterministic studies, and is implicit in making conservative assumptions and using safety margins.

2. STATUS OF THE TOPICAL ISSUE

2.1. ISSUES ON WHICH THERE IS GENERAL AGREEMENT

2.1.1. PSA as a complement of the deterministic approach

All countries operating or constructing nuclear facilities are required to establish legal and governmental mechanisms to ensure nuclear safety, including the establishment of a regulatory body. “Responsibility should be assigned to the regulatory body for authorization, regulatory review and assessment, inspection and enforcement and for establishing safety principles, criteria, regulations and guides” [5]. Historically, this responsibility was implemented using a deterministic approach. Though explicit or implicit probabilistic considerations were included, these were converted to deterministic requirements such as defence in depth, single failure criterion, or definition of safety margins. Many reasons were responsible for this fact: immature probabilistic methodology, limitation of computer hardware and software, limited availability of component failure data and understanding of physical phenomena, limited understanding of human behaviour, etc. Thus, rather than basing the argument on probabilistic considerations, there was more emphasis on requiring redundancy, diversity or safety margins. In addition, probabilistic results are difficult to comprehend — a problem facing PSA even now. Recently, the licensing of nuclear installations is making more extensive and formal use of probabilistic considerations by changing to the use of a deterministic and probabilistic approach. Historically, the use of probabilistic considerations has always been more common in, Argentina, Canada, Netherlands, South Africa, UK and the USA, as well as in some Scandinavian countries.

2.1.1.1. Design safety

Related to design, probabilistic considerations are included in the IAEA's international safety standards. The General Nuclear Safety Objective is defined in Ref. [6] as: "To protect individuals, society and the environment from harm by establishing and maintaining in nuclear installations effective defense against radiological hazards." This is supplemented by two complementary Safety Objectives related to radiation protection and technical aspects. The Technical Safety Objective requires one "To take all reasonably practical measures to prevent accidents in nuclear installations and to mitigate their consequences should they occur; to ensure with a high level of confidence that, for all possible accidents taken into account in the design of the installation, including those of very low probability, any radiological consequences would be minor and below prescribed limits; and to ensure that the likelihood of accidents with serious radiological consequences is extremely low." And further: "The Safety Analysis examines: (1) all planned normal operational modes of the plant; (2) plant performance in anticipated operational occurrences; (3) design basis accidents; and (4) event sequences that may lead to a severe accident". It is specified that "A safety analysis of the plant design shall be conducted in which methods of both deterministic and probabilistic analysis shall be applied". The objectives of both analyses are further specified in the Requirements document and more detailed guidance is given in a supporting Safety Guide [7].

Regarding probabilistic targets, the Safety Guide refers to INSAG-3 [8] and INSAG-12 [9] and states the following: "Safety function or safety system failure probability: Probabilistic targets can be set at a safety function or a safety system level. These are useful to check that the level of redundancy and diversity provided is adequate. Such targets will be plant design specific, so no guidance is provided here. The safety assessment should assess that these targets have been met".

Core damage frequency: For core damage frequency (CDF), INSAG-3 has proposed the following objectives:

— 10^{-4} per reactor-year for existing plants,
— 10^{-5} per reactor-year for future plants.

This is the most common measure of risk since most NPPs have at least a level 1 PSA. In many countries, these numerical values have been used as probabilistic safety criteria (PSC), both formally and informally.

Large release of radioactive material: A large release of radioactive material, which would have severe implications for society and would require off-site emergency arrangements to be implemented, could be specified in a number of ways, including the following:

— Absolute quantities (in Bq) of the most significant nuclides released,
— As a fraction of the inventory of the core,
— A specified dose to the most exposed person off-site,
— As a release giving “unacceptable consequences”.

Probabilistic safety criteria have also been proposed in INSAG-3 for a large radioactive release. The following objectives are given:

— 10^{-5} per reactor-year for existing plants,
— 10^{-6} per reactor-year for future plants.

It is noted in the Safety Guide [7] that instead of this PSC, INSAG-12 states that **“Another objective for these future plants** is the practical elimination of accident sequences that could lead to large early radioactive release, whereas severe accidents that could imply late containment failure would be considered in the design process with realistic assumptions and best estimate analysis so that their consequences would necessitate only protective measures limited in area and in time.”

Health effects to members of the public: INSAG has given no guidance on the targets for health effects for members of the public. In some countries, the target for the **individual risk of death** is taken to be 10^{-6} per reactor-year for members of the public.

The draft IAEA guide on The Format and Content of Safety Analysis Reports for Nuclear Power Plants [10] specifies that a PSA should be incorporated as a chapter of a Safety Analysis Report.

2.1.1.2. Operational safety

A similar trend can be observed with regard to operational safety. The IAEA Requirements for safe operation of NPPs [11] explicitly require the use of PSA for input to the PSR to provide insight into the relative contributions to safety of different aspects of the plant. The Safety Guides supplementing the Requirements for operation recommend using probabilistic methods and approaches as a reasonable tool to ensure the observance of the safety requirements in different areas of NPP operation. Probabilistic assessment methods, together with operating experience, are recommended for the optimization of the operational limits and conditions (OLCs) and for the justification of their modifications. It is recommended that the frequency of the surveillance activities at a power plant be justified based on a reliability analysis including, where available, a PSA methodology.

Reference [11] states that “Data on operating experience shall be collected and retained for use as input for the management of plant ageing, for the evaluation of residual plant life, and for probabilistic safety assessment and periodic safety review.”

The Safety Guide on OLCs and operating procedures [12] recommends that "Consideration should be given to PSA applications in the optimization of OLCs. Probabilistic assessment methods together with operating experience may be used for justification and modification of OLCs." It is further suggested that "The allowable periods of inoperability and the cumulative effects of these periods should be assessed in order to ensure that any increase in risk is controlled to acceptable levels. Methods of probabilistic safety assessment or reliability analysis should be used as the most appropriate means for this purpose. Shorter allowed outage times than those derived from PSA may be stipulated in the OLCs on the basis of other information such as pre-existing safety studies or operational experience." Also, "the surveillance programme should be adequately specified to ensure the inclusion of all aspects of the limits or conditions. The frequency of the surveillances should be stated and should be based on a reliability analysis including, where available, a PSA and a study of experience gained from previous surveillance results or, in the absence of both, the recommendations of the supplier."

Regarding maintenance, it is recommended to optimize the maintenance programme based on the PSA and operating experience. This optimization should ensure that there is a correct balance between preventive maintenance, predictive maintenance, maintenance during power operation or "on-line maintenance" and minimization of breakdown maintenance on safety systems.

The Safety Guide on the qualification and training of NPP personnel [13] recommends training appropriate categories of plant personnel engaged in the emergency preparedness plan to use all available insights including the PSA evaluation to set priorities for the corrective measures.

Thus, a consensus seems to be emerging that an integrated approach using deterministic engineering principles and probabilistic methods and results is a powerful approach to decision making at NPPs. As a national example, in its Probabilistic Risk Assessment (PRA) Policy Statement [14], the NRC stated that "…PRA methods and data should be used in a manner that complements the USNRC's deterministic approach and supports the USNRC's traditional defence-in-depth philosophy". Advocating the use of PSAs in regulatory matters, the same Policy Statement maintains the following: "PRA and associated analyses (e.g. sensitivity studies, uncertainty analyses, and importance measures) should be used in regulatory matters, where practical within the bounds of the state of the art, to reduce conservatism associated with current regulatory requirements, regulatory guides, licensee commitments, and staff practices."

2.1.2. 'Living PSA' as a tool to support risk informed decision making

It is generally recognized and accepted that one important prerequisite for successful PSA application is the availability of a high quality 'living PSA'. Many PSAs in the world have already been maintained as a living PSA framework. It is recognized that the resources dedicated to the living PSA should be coherent with the importance of this work among all the other safety analyses of the plant.

According to Ref. [15]:

> "A 'Living PSA' (LPSA) can be defined as a PSA of the plant, which is updated as necessary to reflect the current design and operational features, and is documented in such a way that each aspect of the model can be directly related to existing plant information, plant documentation or the analysts' assumptions in the absence of such information. The LPSA would be used by designers, utility and regulatory personnel for a variety of purposes according to their needs, such as design verification, assessment of potential changes to the plant design or operation, design of training programmes and assessment of changes to the plant licensing basis."

The above definition implies that, at the initiation of the LPSA project, the documentation associated with the work performed in each task and the project as a whole must be designed to meet two basic requirements:

- — The basis for the LPSA model should be comprehensively documented so that each aspect of the model can be directly related to existing plant information or to the analysts' assumptions of how the plant and the operating staff behave.
- — It must be possible to update the LPSA as changes are made to plant design and operation, feedback is obtained from internal and external operational experience, the understanding of thermal–hydraulic performance or accident progression is improved, and advances are made in modelling techniques.

Regarding updating, the following recommendation applies:

> "The LPSA should be updated **as frequently as necessary** to ensure that the model remains an accurate representation of the safety of the plant. However, continuous updating of the LPSA appears not to be practicable due to reasons such as control of changes, control of documentation and resources required. It is necessary to assess the impact of any modification (design, procedures, operating practices, licensing basis, etc.) on the PSA in order to check its continuing validity and thus to identify any need for updating. While it is likely that each modification will be assessed on a case by case basis, it would be good practice not to accumulate a backlog of such assessments for a period longer than **one year.** Modifications that significantly impact the PSA results may require an immediate updating of the LPSA. However, even if this type of modification does not arise for a longer period, it is still suggested that the

updating process **be audited every three years** and the LPSA formally amended at that time."

Most Member States have no specific requirements for updating the PSA to represent the "as built, as operated" (US concept) plant. Often the updating is related to the refuelling cycle and is for a longer time frame than one year as suggested in the IAEA document.

The quality of the living PSA depends on a well developed and maintained quality assurance (QA) programme that is effectively applied during all PSA phases. The success of developing a living PSA directly depends on the initial QA measures taken. Inadequate QA measures employed in the early stages of a PSA may lead to loss of information and may severely limit the usefulness of the PSA.

Changes in PSA models, data, information and results, including changes to requirements, scope and objectives, and input data, should be made in a controlled manner. The reason for a change has to be documented, and consideration needs to be given to the impact and implications of the change. When carrying out a change, in principle, the modifications should be handled in the same way as for carrying out the complete PSA (information control; configuration control; documentation control; verification and validation; review). This is a key point for the periodic updating of a living PSA. It might be practical for the updating periods to relate to the length of the refuelling cycles.

2.1.3. Safety/risk monitor as a tool to support risk informed decision making

Some PSA applications require the on-line use of the PSA models, and near-prompt knowledge of the instant risk at any time. This requirement can be satisfied by using a special tool called a safety monitor.

Reference [15] defines the safety/risk monitor as follows:

"A Safety Monitor (also referred to as risk monitor) is a plant specific real-time analysis tool used to determine the instantaneous risk based on the actual status of the systems and components. At any given time, the safety monitor reflects the current plant configuration in terms of the known status of the various systems and/or components, e.g., whether there are any components out of service for maintenance or tests. The safety monitor model is based on, and is consistent with, the LPSA. It is updated with the same frequency as the LPSA. The safety monitor is used by the plant staff in support of operational decisions."

Since actual plant operation is dynamic, the risk associated with the plant at any particular time during the year may be different from the average annual risk. The safety/risk monitor provides risk based input for plant configuration management in 'real time', including the evaluation of equipment outages and the combined impacts from the actual plant configuration. This information is useful for maintenance prioritization and for the development of contingency plans during unexpected equipment failures. The safety/risk monitor may provide rapid insights about the potential significance of operational events and precursors, provided that these events are within the scope and limitations of the safety/risk monitor models and assumptions.

Safety/risk monitors vary in scope, level of detail and implementation. For example:

— Some plants only include internal events in their risk monitor. Other plants include internal events and some external events.
— Few plants carry out quantitative risk monitoring during non-power conditions.
— Few plants consider any impacts beyond the equipment being out of service. Other time varying factors such as the condition of operating equipment and plant trip potential are often not systematically quantified.
— The identification of the action thresholds varies significantly between plants, both in the quantitative values used and in the philosophy of how they are established.

Most, but not all, plants have found that effective risk monitoring requires a combination of quantitative and deterministic (defence in depth) considerations.

Risk monitors have many limitations which are often ignored and may not be obvious when these tools are put in the hands of a plant operator. This is further explored in Ref. [16].

The number of risk monitors in use at NPPs has been growing rapidly over the past few years. Experience with their use in the day-to-day decision making process has shown that it is possible to manage the risk in such a way that the peaks in the risk have been reduced in magnitude and duration and there is a significant reduction in the average risk.

2.2. WORK BEING DONE BY MEMBER STATES, THE IAEA AND OTHER INTERNATIONAL ORGANIZATIONS TO ADDRESS REMAINING ISSUES

2.2.1. Efforts to standardize PSA methodology

State of the art PSA methodology is based on a mixture of national and international guidelines, reference PSAs, databases, scientific reference materials and use of commercially available computer tools. It is based on the 'fault/event tree' techniques developed in WASH 1400 [2]. In the absence of a 'PSA standard', the well documented WASH 1400 study was used as a reference study and its principle methodology and some of the data are still being used today. As a basis for staff training, a fault tree handbook [17] was issued and widely distributed internationally by the IAEA in its efforts to promote the use of PSA and to assist its Member States in carrying out PSA studies. More detailed guidance was then provided in the NRC Procedures Guides [18, 19]. At the international level, the IAEA has prepared a series of guidance documents [20–27]. Other major efforts to harmonize PSA methodology are published in Refs [3, 28]. Based on the various broadly consistent guidance documents, many countries have developed their own national guidance. The degree to which the guidance is prescriptive varies, as does the use a country makes of PSA.

From the beginning it was recognized that peer review was an important aspect of ensuring the quality of PSAs. This contributed to reaching a high standard. At the international level the IAEA has been carrying out International PSA Review Team (IPSART) missions (earlier known as IPERS). Specific guidelines for such review missions have been prepared [29] and they use as a reference the IAEA guidance documents and good international practices.

IPSART reviews of PSAs have frequently identified a lack of a rigid QA process in general and a lack of adequate documentation in particular. This is making the peer review very difficult and hinders maintaining the PSA as a living document. It also hinders the review by the regulatory organization and thus reduces its effectiveness for decision making. The IAEA has therefore prepared guidance for QA in carrying out PSAs [30], which includes guidance on PSA model configuration management. The requirements of documentation have been specified in a document providing guidance for the regulatory review of PSAs [31, 32]. Guidance on documentation management for 'living PSAs' is provided in Ref. [15].

Within its IPSART programme the IAEA has performed numerous PSA reviews. Regarding the scope it has been found that in addition to the level of PSA performed and whether or not low power and shutdown states are included, the main differences relate to the treatment of:

— Internal fires and floods (including the 'turbine hall effect');
— External events, in particular seismic events;
— Accident management measures.

With regard to the quality of PSAs, in addition to the issue of documentation and quality control, the main differences relate to the treatment of:

— Large pipe break frequencies,
— Steam generator tube rupture,
— Definition of LOCA success criteria,
— Pump seal failures,
— ATWAS sequences,
— HF modelling,

— Modelling of recovery actions,
— Modelling of CCFs (including IEs).

In the absence of detailed prescriptive standards, the IAEA guidance on the regulatory review of PSAs recommends that at the start of preparing a PSA, agreement is reached with the regulatory body on the exact scope of the study and on acceptable methodologies. The advantage of a non-prescriptive approach is the flexibility provided in encouraging the development of new methodologies. The disadvantage may be the need for a more difficult and detailed review process.

A recommendation on whether to standardize PSA at this time needs to take into account the impact it will have on the existing PSAs, which have been used for years. A standardization effort would need to be justified by a comprehensive analysis of the real necessity for changes in methods and data. It also needs to be considered that requirements from different regulators in different countries (level of detail, level of review, etc.) could lead to different conclusions and applicability of results.

The major ongoing activities in these areas, external to the IAEA, include the development of a draft PSA standard by ASME [33] and the PSA peer review (certification) process developed by the US nuclear industry. Development of the US industry PSA peer review process was initiated by the US Boiling Water Reactor Owners Group (BWROG) and has been adopted for use by the other US NPP owners groups.

2.2.1.1. BWROG certification process

The overall objectives of the BWROG certification process [34] are to assess PSA quality and determine its adequacy for use in assessing specific applications. It is currently applicable to Level 1 and Level 2 PSAs. Certification is something of a misnomer, since no certificate is issued. A better description is a detailed expert peer review process.

The overall PSA quality is not graded (but can be inferred from reviewing the major element grades). The concept is to allow identification of the major PSA elements (and subelements) required to support a specific application and to assess the quality of the PSA in these required areas. For each application the impacted portions of the PSA are to be identified (i.e. elements and subelements) and the scores for these aspects of PSA are reviewed and compared with the required quality grade identified for the application.

The following provides a short summary of the grading used:

— *Grade 1:* This corresponds to the attributes needed for identification of plant vulnerabilities, i.e. responding to NRC Generic Letter 88-20. A PRA with mostly Grade 1 elements is considered acceptable for:

- Satisfying the GL 88-20 requirement,
- Assessing severe accident vulnerabilities,
- Resolving selected generic issues (e.g. A-45),
- Prioritizing licensing issues.

— *Grade 2:* This corresponds to the attributes needed for the risk ranking of systems, structures and components. Examples of such applications include the following:
- MOV ranking for GL 89-10,
- NRC inspection activities,
- Maintenance rule support.

— *Grade 3:* This review grade extends the requirements to ensure that risk significance determinations made by the PRA are adequate to support regulatory applications, when combined with deterministic insights. Examples may include the following:
- Graded QA,
- In-service testing (IST),
- In-service inspection (ISI),
- Backfit calculations (see also Grade 4),
- Reduced or eliminated licensing commitments,
- On-line maintenance evaluations,
- Single Technical Specification changes.

— *Grade 4:* This review grade requires a comprehensive, intensively reviewed study that has the scope, level of detail and documentation to ensure the highest quality of results. Routine reliance on the PRA as the basis for certain changes is expected as a result of this grade. Examples may include the following:
- Reduced or eliminated licensing commitments (sole basis),
- Modify Technical Specifications (sole basis),
- Replace Technical Specifications with an on-line risk monitor,
- Backfit calculations,
- Reclassification of the quality category of some equipment.

It should be noted that a PRA would not require all subelements to receive a Grade 3 in order to be used for a Grade 3 application. Rather, subelement grades less than 3 would require an assessment to determine the impact.

2.2.1.2. ASME standard for PRA for NPP applications

A recent effort by ASME is devoted to developing a PSA standard [33]. In 1998 in the USA, a Standards Committee was formed to develop a national PSA standard to serve as a basis for risk informed applications containing the requirements for

PSAs to be applied, and prescribing and adapting these requirements for specific applications. The draft ASME PSA standard has already been prepared and is under discussion at several forums.

Since the standard is intended for a wide range of applications, corresponding capability categories have been defined. Applications vary with respect to which risk metrics are employed, which decision criteria are used, the extent of reliance on the PRA results in supporting a decision, and the degree of resolution required of the factors that determine the risk significance of the proposed changes. Each application is then evaluated by considering these attributes.

The draft standard states that: "Depending on the application, the required level of PRA capabilities may vary over different elements of the PRA, within a given element, across different accident sequences or classes of accident sequences, initiating events, basic events, end states, and operating modes. While the range of capabilities required for each part of the PRA to support an application falls on a continuum, three Capability Categories are defined in this standard so that requirements can be developed and presented in a manageable way. They are designated as PRA Capability Categories I, II, and III". The attributes of a PRA for each of these Capability Categories are summarized in Table III from this draft standard. For each element of a PSA the standard defines "High Level Requirements" that are the same for all applications, and "Supporting Requirements" (SRs) which are differentiated by Capability Category.

It is recognized that "the boundaries between these Capability Categories are arbitrary. When a comparison is made between the capabilities of any given PRA and the SRs of this Standard, it is expected that the capabilities of a PRA's elements or parts of the PRA within each of the elements will not necessarily all fall within the same Capability Category, but rather will be distributed among all three Capability Categories. Indeed, there may be PRA elements, or parts of the PRA within the elements that fail to meet the SRs for any of these Capability Categories".

The standard also contains the requirements for the PSA configuration control, i.e. how to conduct a "Living PSA" programme.

2.2.1.3. IEC standards

The International Electrotechnical Commission (IEC) issued, in its Standards series, International Standards No. 61508 [35] and No. 300-3-9 [36], dealing with the requirements for risk analysis and functional safety analysis of technological systems specifying the scope of the analysis in general. They intend to provide guidelines for selecting and implementing risk analysis techniques for risk assessment of technological systems. The objective of these standards is "to ensure quality and consistency in the planning and execution of risk analyses and the presentation of results and conclusions." It lists the tasks to be performed when carrying out the risk analysis.

TABLE III. BASES FOR PRA CAPABILITY CATEGORIES (FROM DRAFT ASME STANDARD MATERIALS)

Criteria	Capability Category I	Capability Category II	Capability Category III
1. *Scope and level of detail:* The degree to which resolution and specificity are incorporated such that the technical issues are addressed.	Resolution and specificity sufficient to identify the relative importance of the contributors at the system or train level, including associated human actions.	Resolution and specificity sufficient to identify the relative importance of the contributors at the SSC, including associated human actions level as necessary (see note (a)).	Resolution and specificity sufficient to identify the relative importance of the contributors at the subcomponent level, including associated human actions as necessary (see note (a)).
2. *Plant specificity:* The degree to which plant specific information is incorporated such that the as-built and as-operated plant is addressed.	Plant specific information sufficient for the model to account for the unique design and operational features of the plant.	Plant specific information sufficient for the model to reflect the as-built and as-operated plant (see note (b)).	Plant specific information sufficient for the model to match (or duplicate) the as-built and as-operated plant (see note (b)).
3. *Realism:* The degree to which realism is incorporated such that the expected response of the plant is addressed.	Departures from realism will have a moderate (conservative or acknowledged, potential non-conservative) impact on the conclusion and risk insights as supported by good practices (see note (c)).	Departures from realism will have a small impact on the conclusions and risk insights as supported by good practices (see note c).	Departures from realism will have a negligible impact on the conclusions and risk insights as supported by good practices (see note (c)).

TABLE III. (cont.)

NOTES:

(a) The definition for Category II is not meant to imply that the resolution and specificity are to a level to identify every SSC and human action. Similarly, for Category III, it is not meant to imply that the resolution and specificity are to a level to identify every subcomponent for every component.

(b) The differentiation between ‘account for’, ‘reflect’ and ‘match’ (or ‘duplicate’) is the level of confidence that the model represents the as-built and as-operated plant. In Category I, the model should incorporate realistic or conservative representations of significant features. In Category II, the model should incorporate realistic representations of modelled SSCs consistent with current good practices. In Category III, the model should incorporate accurate representations of modelled SSCs to the extent practical.

(c) Differentiation from moderate (conservative or acknowledged, potential non-conservative), to small, to negligible is determined by the extent to which the impact on the conclusions and risk insights could affect a decision under consideration. This differentiation recognizes that the PRA would generally not be the sole input to a decision. A moderate impact implies that the impact (of the departure from realism) is of such sufficient size that it is likely that a decision could be affected; a small impact implies that it is unlikely that a decision could be affected, and a negligible impact implies that a decision would not be affected.

2.2.2. Risk informed regulations

There are several examples where, on a voluntary basis, plants in the USA have chosen to make use of the 'risk informed' approach to reach relaxation from present specifications. Table IV summarizes the use of risk information in NRC and industry programmes [37] and demonstrates the emphasis given to this approach by various institutions in the USA.

'Risk informed' is part of an integrated decision making process, which includes the need to:

— Comply with the current regulations.
— Maintain the defense in depth approach, i.e. meet deterministic requirements for redundancy, diversity, separation, segregation, equipment qualification, etc.
— Provide for adequate safety margins.
— Demonstrate risk reduction, risk neutral or a small increase in the risk measure.
— Monitor subsequent performance.

The approach includes key comparisons of 'at power', 'transition', or 'shutdown (or mode specific)' risks. Such applications may include the use of compensatory measures, e.g. ensuring the availability of certain systems for relaxation of specifications while performing test or maintenance on the system under consideration.

In the area of in-service inspection, pilot studies at the Surry, Vermont Yankee and Arkansas Nuclear One NPPs have shown an overall risk benefit by reducing personnel radiation exposure, ensuring that inspection activities focus on piping segments with important degradation mechanisms or high failure consequences.

In the area of in-service testing, several studies have led to an adjustment of test frequencies for pumps and valves by categorizing them into those of high or low safety significance, partly under the constraints of ensuring compensatory measures during the tests. A full scope revision programme for the Comanche Peak NPP has shown an increase in the core damage frequency (CDF) of less than 10^{-6} per year which, at a qualitative level, was decided to be risk neutral. It led to adding risk important components to the programme, but led to fewer tests and thus fewer realignment errors.

A pilot South Texas project in the area of graded quality assurance demonstrated that QA efforts could be reduced in a risk neutral application; however, implementation was complicated by other existing regulations.

Regarding the acceptance of risk informed decisions, at present there are two acceptance guidelines applied at the NRC [38], one for CDF and one for Large Early Release Frequency (LERF), both of which should be used. The guidelines for CDF are illustrated in Fig. 1 and the guidelines for LERF in Fig. 2.

TABLE IV. USE OF RISK INFORMATION IN NRC AND INDUSTRY PROGRAMMES

CDF/ DCDF	**RG 1.174 Low CDF/LERF**	**RG 1.174 High CDF/LERF**	**EPRI PSA Application Guide**	**EPRI Temp. Change**	**OL 803**	**Oversight Process SECY-99-007**	**RAG Screening Criteria**	**NEI 91-04 Severe Accident Guidelines**	LERF/ DLERF
10^{-3}									10^{-4}
10^{-4}	Not Normally Allowed	Not Normally Allowed	Unacceptable	Potentially Risk Significant	Substantial Risk Significant	RED Unacceptable	Proceed to Value Impact Analysis (PRIORITY)	Cost Effective Admin. Procedure or Hardware Change or Treat in EOP or include in SAMG	10^{-5}
10^{-5}			Further Evaluation Needed			YELLOW Required Reg. Response	Proceed to Value Impact Analysis”	Cost Effective Admin. Procedure or Hardware Change or include in SAMG	10^{-6}
10^{-6}	Small Changes (Acceptable w/Management Attention)			Assess Non-Quantifiable Factors	Low to Moderate Risk Significance	WHITE Increase Reg. Response	Value Impact Analysis upon Management Decision	Include in SAMG	10^{-7}
10^{-7}	Very Small Changes (Acceptable)	Very Small Changes (Acceptable)	Non-Risk Significant	Non-risk Significant	Very Low Risk Significance	GREEN Routine Reg. response	[No Action]	No Specific Action Required	10^{-8}

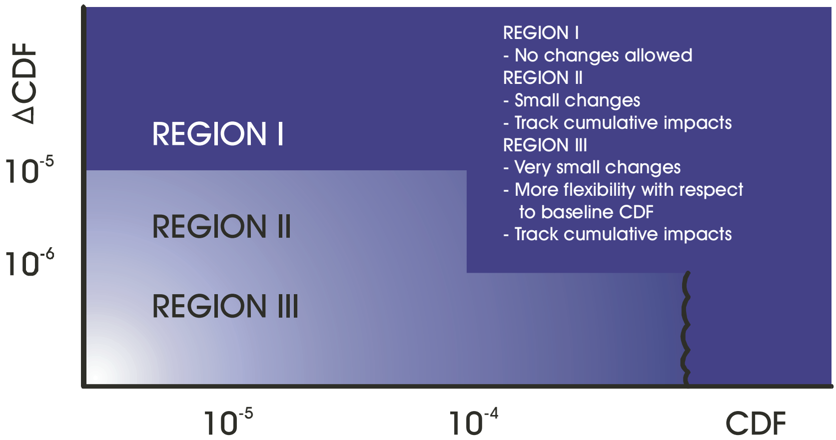

FIG. 1. Acceptance guidelines for CDF.

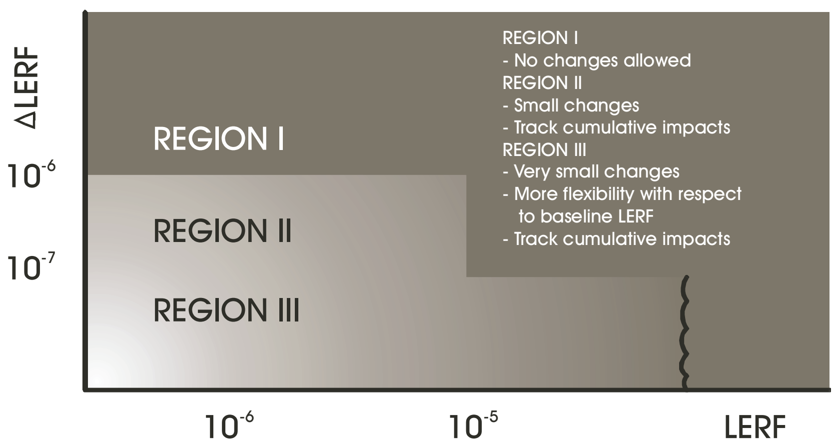

FIG. 2. Acceptance guidelines for Large Early Release Frequency (LERF).

These guidelines are intended to provide assurance that proposed increases in CDF and LERF are small and are consistent with the intent of the NRC's Safety Goal Policy Statement.

These criteria are quite complex in their structure. The regulatory guide further specifies that the acceptance guidelines are to be compared to mean values. However, it is recognized that not all sources of uncertainty are evaluated quantitatively in PSAs. Thus it has been stated as a requirement that the way in which the decision is to be made hinges on whether there are sources of uncertainty that might affect the decision.

The White Paper on Risk-informed and Performance-based Regulation [39] shows the evolution of the NRC approach to regulatory decision making, from the traditional prescriptive approach based on deterministic safety assessment through the risk based approach, the performance based approach to the risk informed and performance based approach. The selection of the new approach started with acknowledgement of the improvements in the performance of the nuclear industry in the USA, moving from prescriptive to performance based regulatory approach and "risk-informing", i.e. including risk based considerations in the new regulatory process.

The NRC has started the 'New NRC Reactor Inspection and Oversight Program' [40], introducing the latest approach to the regulation of the nuclear industry. This is the risk informed, performance based approach to regulation that has been discussed in several forums over the last years. One key area in this approach is the monitoring of the safety performance of NPPs, and the consequent basing of regulatory actions on the actual safety performance. The basis for monitoring safety performance was the identification of 'cornerstones' of safe nuclear plant operation by performance indicators, each categorized to determine the appropriate regulatory response. The 'Significance Determination Process' supports the reactor oversight programme by determining the safety significance of inspection findings and performance indicators, as indicated in Table V. Currently, the approach is applied in all plants, and the first end-of-cycle performance reviews are being evaluated. The development and use of such indicators is explored in detail in Topical Issue Paper No. 5, Safety Performance Indicators.

2.2.3. Regulatory approach in the UK

In the UK, the legal requirement given in the Health and Safety at Work Act 1974 [41] and the Nuclear Installations Act [42] is that risk must be reduced "so far as is reasonably practicable" (SFAIRP) — that is, to a level that is "as low as reasonably practicable" (ALARP).

Guidance for the application of the ALARP principle is given in Tolerability of Risks from Nuclear Power Plants [43] — referred to as ToR. This sets out the framework used for controlling risks at NPPs and introduces the concept of three levels of risk as follows:

TABLE V. NRC MODEL FOR EVALUATING LICENSEE PERFORMANCE INDICATORS

– GREEN –

(ACCEPTABLE PERFORMANCE — Licensee Response Band)

— Cornerstone objectives fully met.
— Nominal risk/Nominal deviation from expected performance.

– WHITE –

(ACCEPTABLE PERFORMANCE — Increased Regulatory Response Band)

— Cornerstone objectives met with minimal reduction in safety margin
— Outside bounds of nominal performance.
— Within Technical Specification limits.
— Changes in performance consistent with ΔCDF$<$E–5 (ΔLERF$<$E–6).

– YELLOW –

(ACCEPTABLE PERFORMANCE — Required Regulatory Response Band)

— Cornerstone objectives met with significant reduction in safety margin
— Technical Specification limits reached or exceeded.
— Changes in performance consistent with ΔCDF$<$E–4 (ΔLERF$<$E–5).

– RED –

(UNACCEPTABLE PERFORMANCE — Plants not normally permitted to operate within this band)

— Plant performance significantly outside design basis.
— Loss of confidence in the ability of the plant to provide assurance of public health and safety with continued operation.
— Unacceptable margin to safety.

— An *unacceptable region* where risks cannot be justified;
— A *tolerable region* where measures must be taken to control the risk and to ensure that they are ALARP;
— A *broadly acceptable region* where the regulator would not press for further safety improvements to be made to reduce the risk.

The Safety Assessment Principles for Nuclear Plants [44] uses this framework and sets out basic safety limits (BSLs) and basic safety objectives (BSOs), which are defined for a number of measures of risk. For example, for the frequency of plant damage (which relates to core damage frequency for a reactor) the BSL is defined as 10^{-4} per year and the BSO as 10^{-5} per year. For the large release frequency, the BSL is defined as 10^{-5} per year and the BSO as 10^{-7} per year.

A further publication, Reducing Risks, Protecting People, issued for public comments in 1999 [45], broadens the framework for regulating the risk from NPPs so that it can be applied to other industrial activities.

The ALARP requirements mean that an employer must do whatever is reasonably practicable to reduce risks. In legal terms, this means that improvements need to be made unless their cost grossly exceeds the reduction in risk. Although formal cost–benefit techniques can be used to assist in making these judgements, this is not generally done in the UK nuclear industry.

3. PROBLEMS IDENTIFIED AND ISSUES TO BE RESOLVED

3.1. REQUIREMENTS OF PSAs FOR USE IN RISK INFORMED DECISION MAKING

Recent developments in a number of countries include expanded utilization of PSA methods and results in risk informed decision making, risk informed operations and regulatory oversight. The main driving force behind this movement is the perception that the use of risk insights can result in both improved safety and a reduction in unnecessary regulatory requirements, hence leading to a more efficient use of the resources of NPP operators and the regulatory authority.

These expanded uses of a PSA place increased demands on the quality and consistency of the PSA. Key questions that arise are: How does one assess quality in a PSA? How much quality is required? How does one ensure consistency?

3.1.1. PSA quality

Judgements on the quality of a PSA are by their nature subjective. However, they are facilitated by clearly defined requirements regarding PSA methods, assumptions and documentation. In addition, a rigid QA process needs to be followed, which also extends to the management of maintaining a ‘living PSA’. Furthermore, a clearly defined process for independent peer review to assess PSA quality is critical.

The **PSA quality should be commensurate with its intended application.** This means that there is not one standard for judging the adequacy of a PSA but that the quality of the PSA must be judged in relation to each specific use or application.

Questions of consistency involve both internal and external aspects. Internal consistency relates to the coherence of PSA methods, assumptions and documentation throughout a specific PSA. External consistency involves these considerations among PSAs for plants of similar design classes. Consistency is fostered by establishing requirements and guidance for performing PSAs, by a structured peer review process and by cross-comparisons of PSAs for similar (and different) designs.

As suggested in the above discussion, the key elements of quality in PSAs are clearly defined requirements and guidance (standards), strictly followed QA procedures and a structured peer review process.

3.1.2. Treatment of uncertainties

An important element of risk informed decision making is adequate consideration of uncertainties. There are two types of uncertainty in PSAs: quantifiable and non-quantifiable uncertainty. Quantifiable uncertainties are related to the random statistical behaviour of equipment failures characterized by a statistical distribution, and to the lack of information to form statistical data in the case of rare events characterized rather by assumed distribution functions with confidence intervals. The advantage of the PSA compared with deterministic studies is that these uncertainties can be evaluated and quantified by rigorous propagation of the basic uncertainties through the model.

On the other hand the uncertainties that are associated with modelling and completeness cannot be quantified. These uncertainties are mostly related to the assumptions made during modelling. They can be evaluated by sensitivity calculations in order to determine the effect of variations of the assumptions on the PSA results, and consequently on the risk informed decision.

The uncertainties increase with the level of the PSA. At higher levels of PSA the role of the assumptions increases and the study includes analyses of the structural behaviour of the containment, or factors like aerodynamic dispersion of radioactive material that further increase the earlier mentioned uncertainties.

Consideration of the uncertainties cannot be avoided, independent of the case deterministic or probabilistic approach. This should be taken into account when making risk informed decisions. They have to be analysed instead. The propagation of the uncertainties of the numerical values of the input data towards the PSA results should be analysed, quantified and documented. The non-quantifiable uncertainties should be analysed by sensitivity calculations in order to determine the influence on the PSA results. Probabilistic safety criteria should be defined in such a way as to take into account the uncertainties.

3.1.3. International PSA standards

In the absence of prescriptive PSA standards there are two complementary ways of ensuring quality and consistency. One possibility is to subject a well documented and available PSA for a certain category of NPP design to a high degree of peer review, and then to use this as the reference PSA. Prominent examples of this approach are the WASH-1400, NUREG-1150, the German Risk Study or EPS-900 and EPS-1300. Another possibility is to establish user groups for similar types of plants and to compare PSA results and analyse the differences. Such user groups have, for example, been established to compare the individual plant examinations (IPEs) in the USA. The IAEA is promoting both approaches by, for example, establishing such groups for PHWRs and for different types of WWER reactors. In addition the IAEA is promoting peer review through its IPSART service. Efforts have been started in Nordic countries to compile information on PSA studies on a CD-ROM, to be available as a reference to those who are performing or reviewing PSAs.

It thus needs to be discussed if at this stage of affairs it is desirable to develop international standards for PSAs.

3.1.4. Peer reviews

At present the activities of IAEA Member States regarding peer reviews of PSAs and PSA applications vary from country to country. As stated earlier, States with several NPPs have specific approaches, including procedures for regulatory review. Some countries request external peer review teams (such as IPSART) to complement national efforts.

Peer reviews serve as a part of the QA process. A typical high level peer review team would consist of five to six experts not involved in the development of the PSA, and the process would cost a 12–15 expert-week effort. Since the peer review cannot cover all the details of the PSA, a full review would involve much more effort. Depending on the licensing approach in the country, the regulatory review can be a fully detailed review, or also a reduced scope peer review. It reflects the needs for expertise to support this regulatory activity.

There is a tendency to perform a peer review of the PSA applications, including the usability of the PSA for the specific application. The ASME Standard mentioned earlier specifies the requirements for and scope of such a review. Also, the IAEA extended its IPSART programme with peer review missions on PSA applications.

At the OECD NEA–CNRA “Special Issues” meeting in 1997, it was recognized by the senior regulators that formal guidance for the regulatory review of a PSA did not exist. A recommendation was made that such guidance needed to be produced to establish an agreed basis for assessing whether important technological and methodological issues were being treated adequately, and to verify that the conclusions reached were appropriate. This guidance is being produced by the IAEA in co-operation with the OECD NEA [31, 32]. These documents raise issues about how the review should be carried out, such as the timing of the review (on-line or off-line), the extent/level of detail of the review and the range of expertise required.

3.2. PROBABILISTIC SAFETY GOALS, ACCEPTANCE CRITERIA

If PSA results are to be used in a formal way for decision making, then it is necessary to establish a formal process for using these results. The details of this process will depend on the purpose of the particular PSA application, the nature of the decision, and the PSA results to be used. When the numerical results of the PSA are to be used, it will often be necessary to establish some reference value with which these results can be compared, as well as a rule, or rules, for how to interpret the results of the comparison. Where the risk informed application is directed towards the identification of the dominant contributors to risk or the optimization (minimum risk) among various design options, plant configurations, testing strategies, etc., there may be no need for a reference value at all. Such uses of PSA, depending only on a relative ranking of values, are often claimed to be the most robust. However, where the application involves judging whether a calculated risk value is acceptable, assessing the acceptability of a proposed change to the plant that would produce a calculated increase in risk, or assessing the need for a change in design or operational practices to reduce the level of risk, then a judgment on the significance of the calculated value can only be made by comparing it with some reference value. These reference values and their associated rules are called probabilistic safety criteria (PSC), and sometimes probabilistic safety goals.

The meaning of the numerical values of the PSC and the decision making rule itself will depend very much on their use. Different PSC are adopted for different decisions. The PSC are specified not only by the numerical values proposed, but also by specifying what value, calculated from the PSA, should be used for comparison purposes, and to indicate how to interpret the results of the comparison. As an example, when specifying the safety goals in its Safety Goal Policy, the NRC specified that the mean values estimated from the PSA were to be compared with the goals, that all contributions to risk were to be considered and that meeting the goal meant that the plants were safe enough.

About ten years ago INSAG-6 [46] concluded that the lack of standardized PSA methodology made it difficult to compare the numerical results of different PSAs. It also concluded that the methodology was not sufficiently mature for its present status to be frozen. But it recognized an emerging international consensus on target probabilities of core damage and large accidental release. The criteria proposed in INSAG-3 [8] and INSAG-12 [9] were discussed in the safety guide on safety assessment and verification [7].

The major issues related to probabilistic safety goals and acceptance criteria to solve in the future are the following.

Different countries apply different values for probabilistic safety goals. In many countries no probabilistic safety goals exist. Although there have been many forums to discuss these goals, and there are even standards dealing with probabilistic acceptance criteria, there is no methodological guidance or procedures on how to establish and what should be the basis for a system of probabilistic safety goals that could be recommended internationally.

The calculated uncertainty ranges of the PSA results are sometimes orders of magnitude wide. The way to handle uncertainties in relation to using the values of probabilistic safety goals also differs from country to country. As already stated, some countries use mean values of the calculated results, while others use values including the calculated uncertainties (confidence levels) to compare the probabilistic safety goals.

There are different approaches to the acceptance of complex decisions containing multiple modifications, changes resulting in a risk or risk increase meeting the acceptance criteria. The risk informed assessment can prove the acceptability of such complex decisions; however, it might be that one or more elements of the decision alone bring unacceptable risk or risk increase, while others serving as compensatory measures result in risk reduction.

The definition of a 'risk neutral' decision should be part of the PSC system. A simple example of a risk neutral decision is one that either does not affect the risk, or causes negligible risk increase (e.g. less than 10^{-7} ΔCDF), and therefore will not be controlled by PSC. In some countries the value of the negligible risk increase has already been defined in the framework of their PSC system. More complicated cases include a trade-off of positive and negative changes (which are not allowed in the USA to be presented in one package) or shifts in the risk curve, if used. There should be an international consensus on the common basis for defining risk neutral decisions.

3.3. COMPUTER SUPPORT FOR RISK INFORMED DECISION MAKING

A number of computer codes and software packages are currently used for performing a PSA. Typically, an integrated software package is used in Level 1 PSAs for the development and storage of system models, sequence models, handling of failure data and sequence quantification. Additionally, other computer codes may be used for the determination of success criteria. Level 2 and Level 3 PSAs also require the use of large computer codes. Finally, smaller pieces of software may be used for special analyses, conversion or transport of data. Increasingly, integrated software packages are developed and used covering almost all levels of a PSA.

In order to ensure QA for the PSA, all computer codes used in the development and application of the PSA must be verified and validated, either in the course of their development or by the PSA group. Computer codes that are purchased commercially may be verified and validated by the code developer. For software that is not commercially procured but, for example, written internally in the PSA organization, verification, validation and QA should be established.

3.4. ORGANIZATIONAL FACTORS

An important aspect of risk informed decision making is that it needs to be agreed to which extent the human factors and aspects of safety culture and organizational aspects will be included. Presently, PSAs model human failure and human action of recovery in case of an accident. Usually the human actions for which written procedures exist are given credit in the PSA. There are standard modelling techniques that are applied. These techniques mostly use generic human error probabilities modified by different factors (known as performance, shaping factors). These performance shaping factors are characterized by corrective values representing the different factors influencing human behaviour and performance, such as the complexity of the task, the human–machine interface, training practice, and the usability of procedures. In an increasing number of PSAs, special human factor studies are applied using the results of the control room crew exercises on the plant simulator. It is good practice to take into account, to the extent possible, plant specific data. Thus, these limited aspects of safety culture and these organizational aspects are taken into account to the extent that they influence human behaviour.

In this regard some experts take the view that organizational aspects should be included in the analysis. Others believe that this is not subject to quantification, adds large margins of uncertainty and opens the door to manipulation of the PSA results. Thus, good safety culture and safety management add an additional layer of protection against accidents which cannot and should not be quantified. In any case, consideration of organizational factors in PSAs should be very practical and not resource consuming.

3.5. FUTURE PASSIVE REACTORS

Risk informed decision making plays an important role in the development of future reactors. Such developments have two objectives: increase in safety and reduction of costs, in particular through simplifying safety systems and reducing the requirements for safety classification of safety systems and components. However, specific problems are involved in performing reliable PSAs for such future reactors making more extensive use of highly reliable passive components. The safety of these reactors is challenged by very severe low probability initiating events. The impact of these events is, to a large extent, determined by the phenomenological response of the plant to these events, rather than by a sequence of successes/failures of components/systems, which individually have higher probabilities and which can be analysed and modelled with much less uncertainty due to the existence of a reliable statistical database. In addition, it is necessary to consider much longer mission times for components of, for example, several days in comparison to the usual 24 hours. Thus, this poses particular methodological problems for making risk informed decisions for these reactor designs which, however, are expected to pose a much lower risk.

4. RECOMMENDATIONS FOR STRATEGIC ACTIONS/PRIORITIES FOR FUTURE WORK

4.1. STRATEGIC ACTIONS

4.1.1. Role of PSA in nuclear safety

The recently revised IAEA Safety Standards give more emphasis to the role of PSA, particularly in the areas of design, periodic safety review and operational safety. Member States should make use of the advances in PSA methodology to improve safety. To this end, regulatory bodies should determine their policy and provide clear guidance on the use of PSA for safety related decision making, on the complementary role of PSA and defence in depth and good engineering practice, and establish the related safety standards and legal basis.

In recent years, there has been a greater use of the risk information provided by PSAs in the regulatory decision making process. However, the way that this is being done varies significantly in different Member States, and indeed some regulators are not following a risk informed approach at all.

Hence, there is a need to review experience in risk informed decision making, how this relates to the legal framework that the regulators are working in, and whether this has increased regulatory effectiveness. In addition, it needs to be determined why some Member States have not adopted a risk informed approach.

4.1.2. Living PSAs, risk/safety monitors

In order to benefit from PSA, regulators and operators should strongly support the idea that plant specific living PSAs be made available at each NPP and used as a complementary tool in making safety related decisions. The current trend is for the living PSAs to be developed into risk/safety monitors, which are used by plant operators during NPP operation and by regulatory bodies. There is a need to provide guidance on the development and use of these risk/safety monitors.

4.1.3. Technical correctness

In order to be useful for safety related decisions, the PSA models have to correctly represent the NPP. In order to achieve technical correctness of the results of

PSA supported safety decisions, countries should employ quality standards for PSAs related to the intended use, establish user groups for similar types of plants, which can include efforts to pool of reliability data, promote the availability of reference studies as benchmarks, and encourage peer review, including use of international peer review services such as the IAEA IPSART service.

4.1.4. Regulatory review of PSAs

It is necessary to avoid the use of low quality PSAs for safety decisions. Therefore, regulatory bodies should increase their efforts to review PSAs. The regulatory bodies need to ensure their technical competence, needed for the review of PSAs and for reviewing and approving safety related analyses and modifications using probabilistic arguments. Guidance documents on regulatory review raise issues, as discussed above, such as the timing of the review (on-line or off-line), and the extent/level of detail of the review.

4.1.5. Probabilistic safety criteria

In order to contribute to regulatory stability and public confidence, regulatory bodies should establish clear criteria for the use of PSA results. These criteria concern:

- — Probabilistic safety targets/goals for the NPPs;
- — Assessment of variations of instant probabilistic measures of the safety level of a plant as obtained from risk/safety monitors (e.g. CD or LERs);
- — Configuration control of the alignment of systems/components, e.g. for testing and maintenance;
- — Measurements of changes of the safety level due to modifications related to design or operation, including the definition of ‘risk neutral’ and the treatment of multiple changes and compensatory measures; and the
- — Treatment of uncertainties or use of confidence intervals in all the above areas.

The recommendations from INSAG have been summarized above. In addition, the issue of defining operational safety criteria, which relate to the instantaneous measures of risk produced by risk/safety monitors needs to be addressed. However, there have been a number of developments in the way that risk criteria have been defined and used in Member States, some of which are discussed in Section 3. There is a need to review these developments and to consider whether it would be possible to reach a consensus.

4.1.6. Key uncertainties

PSA is accompanied by uncertainties at all levels of the analysis, which thus have to be taken into account in the decision making process, as discussed in Section 3.1.2. The key uncertainties are mostly related to areas where the lack of knowledge or information causes uncertainties in particular related to phenomenological aspects such as failures of large pipes or other pressure containing components.

Therefore, Member States and international organizations should review the key contributors to the uncertainties in PSAs and compile experience, carry out research where necessary, and provide guidance on how to reduce these uncertainties.

4.1.7. PSAs for future reactors

In order to increase safety, the proposals being made for future reactors make increasing use of passive systems. This poses methodological problems in a PSA since there is less experience in modelling passive systems compared to active systems. For passive systems to work, a number of boundary conditions need to be met — reactor coolant pressure, etc. — and the PSA needs to determine the probability that these boundary conditions will not be met. In general, it is to be expected that the risk profile of such plants will be significantly different.

It is recommended to review how passive systems are modelled in PSAs and to provide guidance on this topic.

4.1.8. Cost–benefit analysis

A limited number of countries use the results of PSAs within the framework of cost–benefit analysis. It would be useful to compile the experience gained in these countries and to analyse the factors which should be considered.

4.1.9. Wider use of PSA

At present, PSA methodology is mainly applied in the area of the safety of NPPs, though some more limited use has been made for research reactors, other fuel cycle installations, isotope production facilities, large irradiation facilities, etc. Guidance [47] has recently been provided on conducting PSAs for non-reactor fuel cycle facilities. For many facilities a simplified approach may be taken. The depth and detail of the analysis should be commensurate with the level of hazard posed by a facility. Due to the wide range of facilities, there are limited generic component reliability data and even less plant specific data available. With due consideration of these limitations, it is nevertheless strongly recommended to make greater use of PSA beyond NPP applications to identify the vulnerabilities of a facility design or configuration, and critical human actions important to safety.

5. QUESTIONS TO THE CONFERENCE

A. Introduction of risk informed decision making in Member States

(1) Is there sufficient consensus regarding the introduction of risk informed decision making into nuclear safety? Why are some countries still hesitant?

(2) Is risk informed regulation increasing regulatory effectiveness?

(3) Is risk informed regulation of benefit to utilities?

(4) Are regulators prepared to review PSAs and PSA applications? How much effort is needed?

B. Criteria to be used in risk informed decision making

(5) What PSC are needed to facilitate risk informed regulation? Is there a sufficient legal basis for risk informed decision making?

(6) Is it possible to define ‘risk neutral’ decisions?

(7) Why is there no international agreement on PSC? Is international agreement wanted? What should be done to reach agreement?

C. Quality of PSAs as a basis for risk informed decision making

(8) Is there sufficient guidance for the preparation of high quality PSAs? Is there a need for an international standard for PSAs?

(9) Is PSA methodology sufficiently developed to support ‘risk informed’ regulation, e.g. treatment of rare events, modelling of human failure, severe accident management, organizational factors? Is PSA methodology sufficiently developed to model new reactor designs that are more dependent on passive features?

(10) How is it possible to ensure that operators are in a position to develop, use and maintain living PSAs and risk/safety monitors to support ‘risk informed’ decisions?

D. International co-operation

(11) What actions should be taken by the IAEA to support the introduction of ‘risk informed’ decision making, e.g. as related to the areas of the development of international standards, harmonization of criteria, compilation and dissemination of experience, and education and training?

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Applications of Probabilistic Safety Assessment (PSA) for Nuclear Power Plants, IAEA-TECDOC-1200, IAEA, Vienna (2001).
[2] UNITED STATES NUCLEAR REGULATORY COMMISSION, Reactor Safety Study: An Assessment of Accident Risks in US Commercial Nuclear Power Plants, WASH-1400-MR (NUREG-75/014), NRC, Washington, DC (1975).
[3] UNITED STATES NUCLEAR REGULATORY COMMISSION, Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, Rep. NUREG-1150, NRC, Washington, DC (1990).
[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Advances in Reliability Analysis and Probabilistic Safety Assessment for Nuclear Power Reactors, IAEA-TECDOC-737 IAEA, Vienna (2000).
[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety, Safety Standards Series No. GS-R-1, IAEA, Vienna (2000).
[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Design, Safety Standards Series No. NS-R-1, IAEA, Vienna (2000).
[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment and Verification for Nuclear Power Plants, Safety Standards Series No. NS-G-1.2, IAEA, Vienna (2001).
[8] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Basic Safety Principles for Nuclear Power Plants, Safety Series No. 75-INSAG-3, IAEA, Vienna (1988).
[9] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Basic Safety Principles for Nuclear Power Plants 75-INSAG-3 Rev. 1, INSAG-12, IAEA, Vienna (1999).
[10] INTERNATIONAL ATOMIC ENERGY AGENCY, The Format and Contents of Safety Analysis Reports for Nuclear Power Plants, draft Safety Guide (unpublished).
[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Operation, Safety Standards Series No. NS-R-2, IAEA, Vienna (2000).
[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants, Safety Standards Series No. NS-G-2.2, IAEA, Vienna (2000).
[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Recruitment, Qualification and Training of Personnel for Nuclear Power Plants, Safety Standards Series No. NS-G-2.8, IAEA, Vienna (2002).
[14] UNITED STATES NUCLEAR REGULATORY COMMISSION, The Probabilistic Risk Assessment (PRA) Policy Statement (60 FR 42622), USNRC, Washington, DC (1995).
[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Living Probabilistic Safety Assessment (LPSA), IAEA-TECDOC-1106, IAEA, Vienna (1999).
[16] FLEMING, K.N., Validation of PSAs for use in risk monitoring applications, ASME J. Pressure Vessel Technol. **120** (1998) 379–383.
[17] UNITED STATES NUCLEAR REGULATORY COMMISSION, Fault Tree Handbook, NUREG-0492, NRC, Washington, DC (1981).

[18] UNITED STATES NUCLEAR REGULATORY COMMISSION, Probabilistic Risk Analysis: Procedures Guide, Rep. NUREG/CR-2300, NRC, Washington, DC (1983).

[19] UNITED STATES NUCLEAR REGULATORY COMMISSION, Probabilistic Risk Analysis: Procedures Guide, Rev. 1, Reps NUREG/CR-2815 and BNL-NUREG-51559, NRC, Washington, DC (1985).

[20] INTERNATIONAL ATOMIC ENERGY AGENCY, The Role of Probabilistic Safety Assessments and Probabilistic Safety Criteria in Nuclear Power Plant Safety, Safety Series No. 106, IAEA, Vienna (1992).

[21] INTERNATIONAL ATOMIC ENERGY AGENCY, Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 1), Safety Series No. 50-P-4, IAEA, Vienna (1992).

[22] INTERNATIONAL ATOMIC ENERGY AGENCY, Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 2), Safety Series No. 50-P-8, IAEA, Vienna (1995).

[23] INTERNATIONAL ATOMIC ENERGY AGENCY, Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 3), Safety Series No. 50-P-12, IAEA, Vienna (1996).

[24] INTERNATIONAL ATOMIC ENERGY AGENCY, Human Reliability Analysis in Probabilistic Safety Assessments of Nuclear Power Plants, Safety Series No. 50-P-10, IAEA, Vienna (1995).

[25] INTERNATIONAL ATOMIC ENERGY AGENCY, Treatment of External Hazards in Probabilistic Safety Assessments for Nuclear Power Plants, Safety Series No. 50-P-7, IAEA, Vienna (1995).

[26] INTERNATIONAL ATOMIC ENERGY AGENCY, Probabilistic Safety Assessments of Nuclear Power Plants for Low Power and Shutdown Modes, IAEA-TECDOC-1144, IAEA, Vienna (2000).

[27] UNITED STATES NUCLEAR REGULATORY COMMISSION, Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, Final Summary Report, Rep. NUREG/CR-1150, NRC, Washington, DC (1990).

[28] UNITED STATES NUCLEAR REGULATORY COMMISSION, Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance, Rep. NUREG-1560, NRC, Washington, DC (1997).

[29] INTERNATIONAL ATOMIC ENERGY AGENCY, Procedures for Conducting Independent Peer Reviews of Probabilistic Safety Assessment, Guidelines for the International Peer Review Service (IPERS) Programme, IAEA-TECDOC-832, 2nd edn, IAEA, Vienna (1995).

[30] INTERNATIONAL ATOMIC ENERGY AGENCY, A Framework for a Quality Assurance Programme for PSA, IAEA-TECDOC-1101, IAEA, Vienna (1999).

[31] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulatory Review of Probabilistic Safety Assessments (PSA) Level 1, IAEA-TECDOC-1135, IAEA, Vienna (2000).

[32] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulatory Review of PSA Level 2, IAEA-TECDOC-1229, IAEA, Vienna (2001).

[33] AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Standard for Probabilistic Safety Assessment for Nuclear Power Plant Applications, draft, ASME, New York.

[34] BOILING WATER REACTOR OWNER'S GROUP, Report to the Industry on PSA: Peer Review Certification Process: Pilot Plant Results, January 1997.

[35] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Functional Safety of Electrical/Electronic/Programmable Electronic Safety Related Systems — Part 1: General Requirements, International Standard IEC 61508, IEC, Geneva (1998).

[36] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Risk Analysis of Technological Systems, International Standard IEC 300-3-9, IEC, Geneva (1995).

[37] REINHARD, M., Presentation at CNRA Meeting, OECD/NEA, Paris, 29–30 November 1999.

[38] UNITED STATES NUCLEAR REGULATORY COMMISSION, An Approach for Using Probabilistic Risk Assessment in Risk-informed Decisions on Plant Specific Changes to the Licensing Basis, Regulatory Guide 1.174, NRC, Washington, DC (1998).

[39] UNITED STATES NUCLEAR REGULATORY COMMISSION, Risk-informed and Performance-based Regulation, *http://www.nrc.gov/NRC/COMMISSION/policy/whiteppr.html* (2000)

[40] UNITED STATES NUCLEAR REGULATORY COMMISSION, New NRC Reactor Inspection and Oversight Program, Rep. NUREG-1649, Rev. 1, NRC, Washington, DC (1999).

[41] UK HEALTH AND SAFETY EXECUTIVE, Health and Safety at Work Act (1974).

[42] UK HEALTH AND SAFETY EXECUTIVE, Nuclear Installations Act (1965).

[43] UK HEALTH AND SAFETY EXECUTIVE, The Tolerability of Risks from Nuclear Power Stations, HMSO, London (1988).

[44] UK HEALTH AND SAFETY EXECUTIVE, Safety Assessment Principles for Nuclear Plants, HMSO, London (1992).

[45] UK HEALTH AND SAFETY EXECUTIVE, Reducing Risks, Protecting People, HSE Books, London (1999).

[46] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Probabilistic Safety Assessment, Safety Series No. 75-INSAG-6, IAEA, Vienna (1992).

[47] INTERNATIONAL ATOMIC ENERGY AGENCY, Procedures for Conducting Probabilistic Safety Assessments for Non-Reactor Nuclear Facilities, IAEA-TECDOC-1267, IAEA, Vienna (2002).

Keynote Paper

RISK INFORMED SAFETY AND REGULATORY DECISION MAKING
An NRC perspective

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Abstract

RISK INFORMED SAFETY AND REGULATORY DECISION MAKING: AN NRC PERSPECTIVE.

To accomplish its mission in the coming years, the United States Nuclear Regulatory Commission (NRC) has established a set of four strategic objectives or performance measures by which it can plan, budget, perform and manage its activities: to maintain safety, to increase regulatory effectiveness and efficiency, to reduce unnecessary regulatory burden, and to increase public confidence. Measures are now being developed to assess the NRC's performance in these areas to communicate with stakeholders and demonstrate accountability for its resources. One of the key strategies for accomplishing the NRC's goals is to risk inform its regulations through the use of probabilistic risk analyses, or PRAs. In making risk informed decisions on changing its regulatory framework, the NRC relies on five key principles, as discussed in NRC Regulatory Guide 1.174: (1) does the change continue to meet current regulations? (2) has defence in depth been appropriately considered? (3) is a sufficient safety margin maintained? (4) are the changes in core damage frequency and large early release frequency small? and (5) how are the impacts of the changes monitored? The NRC has undertaken a number of risk informed initiatives based on the general guidance provided in Regulatory Guide 1.174. The NRC has risk informed initiatives in technical specifications, in-service inspection and testing, the reactor oversight process, relaxation of special treatment requirements, and revisions to technical requirements. As the NRC moves forward with increased use of risk informed techniques, it must also undertake the effort to communicate with stakeholders to receive input and explain its activities. That is why the NRC is conducting mandatory PRA training for staff, holding workshops with industry and the public, and generally reaching out to ensure that its efforts in this area are both visible and understandable. The vision for the final product of this complex process is a regulatory structure or framework that is more aligned with safety and risk significance, more internally consistent and easier for NRC licensees and the public to understand and for NRC staff to implement. As the process moves forward, the overall regulatory burden will be reduced while maintaining safety, public confidence will be improved and the NRC will become more efficient and effective.

1. NRC PRIORITIES

The first point to emphasize is the unchanging bedrock on which the United States Nuclear Regulatory Commission (NRC) must build its regulatory system. The fulfillment of the promise of nuclear energy is crucially and absolutely dependent on the maintenance of safe operations. The NRC's — and the industry's — highest priority must be the protection of public health and safety.

To accomplish its mission in the coming years, the NRC has established a set of four strategic objectives or performance measures by which we plan, budget, perform and manage our activities: to maintain safety, to increase regulatory effectiveness and efficiency, to reduce unnecessary regulatory burden and to increase public confidence. We are developing measures to assess our performance in these areas to communicate with stakeholders and to be accountable for our resources.

The first and highest priority — **maintaining safety** — reflects the NRC's commitment to ensuring that good safety practices are utilized in the management and operation of nuclear facilities. This will be a significant challenge for the NRC and its licensees during a time of industry business consolidation and increased economic pressures due to industry deregulation. Maintaining safety embraces the approach that there exists an acceptable level of safety contrasted by 'never safe enough', with backfitting concerns.

To address the second and third objectives — **increasing effectiveness and efficiency** and **reducing unnecessary regulatory burden** — the NRC is seeking to focus attention on issues of the highest safety significance while achieving the mandate to incorporate risk informed/performance based insights into the regulatory framework. To accomplish this goal, the NRC is utilizing probabilistic risk assessments (PRAs), sometimes called probabilistic safety assessments, as tools to 'risk inform' its activities and regulations. These tools are not free of uncertainties and thus they are used to inform our processes and decisions, not to provide the sole basis for them.

Finally, the NRC recognizes that building and maintaining public trust is critical to the achievement of success for the regulator. The NRC must both be, and be perceived to be, an independent, open and conscientious regulator. To achieve this aim, the NRC must make public participation in the regulatory process more accessible and it must be objective in its examination of nuclear power plant performance. Our goal is to be a strong, credible regulator.

Achieving these objectives presents special challenges in a time of transition in the nuclear industry to deregulation, consolidation and licence transfers, including foreign ownership of vendors/services. The NRC must be ready to adapt, as appropriate, to the effects of changing financial pressures on its licensees — pressures to cut costs coupled with pressures to achieve improved operating performance. The

NRC's mission and its performance goals serve as the guide to focus our efforts during this turbulent period.

The main challenges facing us are:

— Where to focus limited regulatory resources, and how to measure regulatory performance?
— When appropriate, minimize the regulatory burden — do not distract industry resources from achieving a high level of safety performance by identifying and correcting issues through effective problem identification/corrective action programmes.

To achieve these goals the NRC is developing, and in some cases informing, our regulatory decisions with an understanding of risks.

One of the key strategies for accomplishing the NRC's goals is to risk inform its regulations through the use of PRAs. However, the NRC's decisions are not made solely on the basis of the results of a PRA analysis. Due to the uncertainties associated with modelling methods and assumptions on equipment and human performance, an integrated approach to decision making is needed that appropriately factors in the risk insights provided by PRA with insights from more deterministic methods used to provide confidence that safety is maintained. In making risk informed decisions on changing its regulatory framework, the NRC relies on five key principles, as discussed in NRC Regulatory Guide 1.174: (1) does the change continue to meet current regulations? (2) has defence in depth been appropriately considered? (3) is a sufficient safety margin maintained? (4) are the changes in core damage frequency and large early release frequency small? (5) how are the impacts of the changes monitored?

2. RISK INFORMED INITIATIVES

The NRC has undertaken a number of risk informed initiatives based on the general guidance provided in Regulatory Guide 1.174. It has risk informed initiatives in technical specifications, in-service inspection and testing, the reactor oversight process, relaxation of special treatment requirements, and revision to technical requirements.

The NRC has found, by applying an integrated decision making process that incorporates risk insights, that reducing unnecessary regulatory burden can be achieved while maintaining public health and safety. A brief summary of the areas where the NRC has had recent success in applying risk informed decision making is provided.

In the area of technical specifications, the NRC has applied risk insights to provide generic guidance to increase allowed outage times for equipment. This has been accomplished through the Consolidated Line Item Improvement Process that allows NRC licensees to request technical specification changes using generic safety evaluations approved by the NRC. Further, the NRC is currently evaluating a number of other initiatives proposed by the US nuclear power industry. These initiatives include, for example, removing non-risk significant systems requirements from technical specifications and removing non-safety surveillance requirements and all surveillance requirement frequency requirements from technical specifications.

Risk informed technical specification initiatives include eight topical areas, with a short term focus on three, including pilot plant applications before the end of 2001. This programme puts risk informed decision making in the control room in the next four months.

In the area of in-service inspections (ISIs), the NRC has granted relief from the scope of locations requiring examination using risk informed information. Currently, the NRC has granted relief to 14 units, and has requests related to 28 units under review. The number of locations examined under a risk informed ISI programme can be reduced by up to about 70% compared with a traditional ISI programme.

One of the more important initiatives to risk inform the NRC's regulatory framework is an improved reactor oversight process. The NRC's aim was to produce a system that allocated the inspection effort to those matters important to safety, while providing greater objectivity and transparency. Previous NRC regulatory programmes were effective but not responsive to developing challenges such as: industry deregulation, economic pressures, public access to information on plant performance and regulatory decisions. The NRC developed performance indicators (PIs) to allow the systematic assessment of plant performance over time, coupled with a baseline inspection programme that is focused on risk significant issues. Objectivity is served by a new and systematic process for assessing performance, coupled with predefined actions that flow from risk significant findings. Transparency is served by making the process, PI data and inspection reports available to all, including through the NRC web site. This process was developed with input from and the direct participation of stakeholders, including States, industry, NGOs and media representatives.

The NRC has also launched a close examination of special treatment requirements — the rules governing equipment deemed to be safety related. With insights provided from PRAs, the NRC now realizes that some equipment that has historically been categorized and treated as safety related, and thus subject to special restrictions, in fact only makes a limited contribution to risk and is therefore eligible for relief from regulatory requirements. Conversely, other equipment that was not previously categorized as safety related is now understood to have safety significance and is therefore eligible for enhanced treatment. The NRC is engaged in an extensive process to rethink the regulatory requirements that bear on these categories of equipment. As a proof of concept for this approach, the NRC granted the South Texas Project (a four loop Westinghouse two unit site) exemptions from a number of special treatment requirements related to commercial grade dedication, seismic and environmental qualification, ISI and testing, repair and replacement, and containment isolation valve leak rate testing. Initial estimates are $2 million savings per year. Other efforts to risk inform NRC regulatory requirements include the standards for combustible gas control systems [10 CFR 50.44] and the acceptance criteria for emergency core cooling systems [10 CFR 50.46].

3. OTHER INITIATIVES

The NRC is engaged in the development of PRA standards. This includes preparation of national standards, the Nuclear Energy Institute (NEI) Peer Review Process (which has been completed for the majority of plants), and the UCS/NRC observation of the NEI programme. In addition, the NRC is developing a risk informed construction inspection programme.

As the NRC moves forward with increased use of risk informed techniques, it must also undertake the effort to communicate with stakeholders to receive input and explain its activities. Modification of the regulatory processes cannot be satisfactorily achieved without acceptance of the approach by NRC staff and stakeholders. That is why it is conducting mandatory PRA training for staff, holding workshops with the industry and the public, and generally reaching out to ensure that our efforts in this area are both visible and understandable. The NRC needs to establish an understanding of its approach so that its stakeholders, including the general public, have confidence that its efforts to modify regulations are not whimsical, or designed to favour or to harm licensees, but rather are firmly based on the best information that is now available using the best analytical tools.

The vision for the final product of this complex process is a regulatory structure or framework that is more aligned with safety and risk significance, more internally consistent, and easier for NRC licensees and the public to understand and for NRC staff to implement. As the process moves forward, the overall regulatory burden will be reduced while maintaining safety, public confidence will be improved and the NRC will become more efficient and effective.

4. CONCLUSION

To reinforce Mr. ElBaradei's remarks, many of you have participated in regulatory exchanges to observe and contribute to NRC regulatory programmes, Canada, China, France, Japan, Spain and the United Kingdom to name a few. Additionally, we have recently initiated long term assignments from the USA to France and Switzerland to gain insights into other nations' programmes. As Charles Packer noted, the NRC is continually learning and raising its internal performance standards.

Keynote Paper

VIEWS OF THE FRENCH NUCLEAR SAFETY AUTHORITY ON RISK INFORMED APPROACHES AND ON THE USE OF PROBABILISTIC SAFETY ASSESSMENT

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Abstract

VIEWS OF THE FRENCH NUCLEAR SAFETY AUTHORITY ON RISK INFORMED APPROACHES AND ON THE USE OF PROBABILISTIC SAFETY ASSESSMENT.

Probabilistic safety assessments (PSAs), which provide information on the level of risk, are one of the tools that can be used to make risk informed decisions, but not the only one. In France, there are many reasons why the PSAs of pressurized water reactors can be deemed to be satisfactory. They have been used quite extensively, mainly to improve safety and to aid in ranking safety problems by order of importance. However, the experience gathered in this field suggests that regulators as well as utilities should be aware of the limitations of PSAs. The French Nuclear Safety Authority encourages the use of PSAs as a tool for improving safety, but does not encourage their use for reducing regulatory requirements. Additionally, in the French context, setting regulatory acceptance criteria for PSA results does not appear to be appropriate. Consequently, the French Nuclear Safety Authority believes that the development of international guidance for the preparation of high quality PSAs that calls attention to their limitations would be useful. But the French Nuclear Safety Authority is not in favour of establishing recommendations for probabilistic safety criteria or for developing guidance on the purposes for which PSAs should be used.

1. INTRODUCTION

In recent years, the nuclear safety authorities of some Member States have emphasized the need to use extensively probabilistic safety assessments (PSAs) to support decision making in the field of nuclear safety. The international nuclear community now commonly refers to these practices as ‘risk informed approaches’. It is worth keeping in mind that the words ‘risk informed’ do not refer in themselves to the use of probabilistic assessments, and that if decisions related to nuclear installations have to take into account the level of risk, PSAs are only one of the tools that can be used to assess risk and make risk informed decisions.

Taking into account the wide experience gained in France with the development and utilization of PSAs, this paper discusses how PSAs can contribute to good decision making — if certain conditions are met. It shows that, on account of their limitations, PSAs have to be used cautiously and should not be the only method used for risk assessment. Finally, the use of PSAs to reduce constraints on the licensee, and the interest in setting probabilistic criteria, are discussed in a context in which the safety authority's aim is to improve safety.

2. BENEFITS OF PSA FOR REGULATORY DECISION MAKING

2.1. Factors favourable to the development of high quality PSAs in France

Although the safety of French PWRs relies on deterministic principles, the probabilistic approach has been considered since the 1970s as an important complement to safety analysis. Several factors have contributed to the development of high quality PSAs in France:

— The reliability data used in PSAs were founded on the operating experience of Electricité de France (EdF); due to the standardization of the French PWR design, very high quality data could be obtained.
— Special attention was paid to data on human factors; a large number of simulator experiments have been undertaken to collect information.
— Components were considered to a high level of detail.
— All operational phases of the plant, including shutdown states, were taken into account.

The PSAs have been developed independently by both EdF, the utility, and by the Institut de protection et de sûreté nucléaire (IPSN), the main technical support organization of the French Nuclear Safety Authority, in collaboration with Framatome, the manufacturer. However, the important problems related to methods and data were discussed together, and extensive mutual external reviews by EdF and IPSN were very helpful to assess the depth of the PSA as well as the validity of the various assumptions made.

2.2. PSAs as a valuable tool for decision making

PSAs have been used successfully to complement deterministic demonstrations in design and operational issues, and thus improve safety. They have also been used to rank safety concerns by order of significance. Examples of PSA utilization in France are:

— Reassessment of the list of multiple failure events (complementary operating conditions) and verification of the related procedures;
— Identification during safety reassessments of sequences that have a high contribution to core melt frequency, in order to define necessary modifications;
— As a complement to the deterministic design studies for EPR;
— Verification of the plant unavailability time limits authorized in technical specifications;
— Optimization of maintenance;
— Selection of incidents to be analysed in depth;
— Assessment of the risk when an example of non-conformance is discovered.

It can be said that, although the completion of PSAs was not a regulatory requirement, France has acquired broad experience in the development and use of PSAs. To help to maximize the benefit of this experience, the French Nuclear Safety Authority has decided that a basic safety rule on PSA methodology should be written. IPSN is currently working on this task, with the participation of EdF.

3. PSA LIMITATIONS

3.1. PSAs should be used with care

As a tool for risk assessment, PSAs are worth considering as part of the regulatory decision making processes; they contribute to increased regulatory efficiency. But the experience gained with PSAs suggests that they should be used with care. In particular, the 'intelligent user' of PSAs should first be aware of their limitations, and secondly be sufficiently familiar with the methodologies used in PSAs: indeed, it would not be acceptable for a regulatory body to make decisions on the basis of a tool that has not been properly understood.

It is worthwhile to review some of the key elements which can limit the use of PSAs:

— The variability of their results, which depend greatly on the input data, has to be kept in mind; this underscores the importance of discussions between the utility and the regulatory body on the data. Uncertainties can also stem from the model chosen. An illustration of this is the French–Belgian comparison that has been made between the PSA of EdF's 900 MW(e) reactors, and the PSA of

Tihange 1, the design of which is similar. For some ‘families’ of sequences, there are significant discrepancies between the evaluations of core damage frequency; these discrepancies have been attributed mainly to differences in the hypothesis or in the models.

— The input data of PSAs, which are component reliability data, are based on experience feedback, i.e. on the observation of the past. As a consequence, PSAs are not very well adapted for anticipating new safety issues. In addition, regarding components with very low fault rates, the reliability data may not be statistically significant.
— At the present time, in France, PSAs are only level 1 or 1+, which means that they only address core damage risk. They deal neither with the containment function, nor with external releases. Level 2 PSAs are in progress, but given the broad uncertainties on the physical phenomena following core damage, and on the containment behaviour, their results will have to be used very carefully.

3.2. Being ‘risk informed’ does not signify relying on PSAs exclusively

In addition to the intrinsic limitations of the PSAs, it is emphasized that, as said previously, the concept of ‘risk informed’ should not be limited to the use of PSAs. For instance, PSAs do not properly deal with organizational or safety culture issues. If we look at some of the most important issues that are currently being dealt with by the French Nuclear Safety Authority, namely the organizational problems in Dampierre, the fuel assembly failures in Cattenom 3, the leaktightness concerns of the double wall containment buildings, the flooding of Blayais, none of them has been predicted nor addressed by using a PSA.

Additionally, one should not forget that even though PSAs are not available for nuclear installations other than power reactors (e.g. fuel cycle and waste storage facilities), decisions made on these installations do consider the risk related to their operation.

Indeed, if we define ‘risk’ as a danger to which somebody is more or less likely to be exposed, we can consider that a ‘risk informed’ approach is used:

— When selecting postulated initiating events, as is done in the deterministic safety case;
— When identifying sources of danger from experience feedback;
— When assessing organizational concerns.

Moreover, it would seem necessary to resort to other methods of risk assessment not only to complement PSAs, but also to maintain a questioning attitude and critically consider their results.

4. PSA AND SAFETY OBJECTIVES

4.1. Discussion on constraints

In France, the general safety objectives are set by the Nuclear Safety Authority. The definition and implementation of technical solutions principally rely on continuous discussions between the utility and the safety bodies (the Nuclear Safety Authority and its technical support organization). This ongoing dialogue, which enables a continuous improvement of safety, goes together with a rather non-prescriptive regulation: indeed, the Nuclear Safety Authority has preferred to develop a set of basic safety rules which are not regulatory requirements but guides for good practices. Plant operation, however, is performed according to more detailed specifications initially proposed by the licensee; these documents are approved by the Nuclear Safety Authority in their final version. In line with this approach, the Authority does not intend to go beyond a basic safety rule for PSAs and does not intend to develop additional regulatory requirements on this topic.

The aim of the Authority is to improve safety, not just to maintain it. Therefore, we encourage the development and use of PSAs for improving safety, and not for reducing regulatory requirements — this could be the aim of the utility. Up to now in France, in practice, EdF did not propose to use PSAs to reduce existing constraints, except in some rare cases in the technical specifications of the power plants. EdF's approach in this field is quite cautious.

However, if there was a need for reducing the 'regulatory burden' or for making 'risk neutral' decisions, the following remarks should be considered.

— Demonstrations are to be done by the utility, not by the regulatory body: if the regulatory body has to demonstrate that the regulation is reduced to the minimum, there is a big risk that some justified requirements might disappear just because the regulatory body has difficulty in demonstrating that they are necessary.
— Pursuant to the principles of safety culture, a cautious approach should prevail regarding safety concerns. Therefore, reducing requirements should require more justifications than enhancing requirements. Furthermore, every reduction should be analysed by examining the consequences of the reduction on the overall safety case.

4.2. Probabilistic safety criteria

As stated, the role of the Nuclear Safety Authority is to set objectives — not necessarily quantitative — and it is also to examine the means proposed by the licensee to achieve these objectives. Even where the objectives are met, this should not prevent the Authority from discussing the means used.

In this context, setting acceptance criteria for PSA results does not seem to be worthwhile. The quantitative probabilistic safety objectives which were set in 1977 by the Authority are useful guidance, but they are not used as limits for which compliance has to be demonstrated.

More generally, the setting of probabilistic criteria raises the following issues:

— Risk acceptance is not merely a technical issue.
— As the PSA results are highly dependent on the input data and on the models used, as discussed in Section 3, adopting strict limits to be respected in the safety demonstration is technically difficult. If they were set, the utility could be tempted to build the PSA in a way that best enables them to respect the limits.
— The perverse effect of setting limits must also be considered. Once the utility has demonstrated that the limit is respected, they may lack the incentive to improve safety, even if the safety improvement can be done at low additional cost.

Altogether, the use of PSAs for relative considerations (dominant sequences, comparison of plant states, ranking of problems) seems to be more fruitful than their use for verification of compliance with absolute criteria.

5. CONCLUSION

France has acquired valuable experience in the development and utilization of PSAs. The French Nuclear Safety Authority considers them to be an effective tool, notably for improving the safety of French PWRs, by identifying where design and operating modifications are worthwhile, and for ranking problems in terms of their safety importance. However, PSA users should be aware of their limitations, and of the fact that they are not the only tool for risk evaluation. Indeed, generally in France, decisions have not relied totally on probabilistic assessments: other elements, such as experience feedback, safety studies and engineering judgement, have also been considered.

As the French Nuclear Safety Authority’s aim is to improve safety, we consider that the use of PSAs to reduce constraints on the utility should not be encouraged in safety standards. For improving safety, we believe that the use of PSAs for relative consideration is more efficient than the use of absolute criteria.

We therefore consider that on an international level, it would be of great interest to utilize international experience to produce guidance on the development of high quality PSAs. However, this guidance should not deal with the utilization of PSAs, nor should it deal with probabilistic criteria, as these issues depend very much on the national safety policy adopted.

Lead-in Discussion

TRANSITION TO RISK INFORMED DECISION MAKING

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I am pleased to join you in this discussion session on Topical Issue No. 1: Risk Informed Decision Making. Given the agenda discussion topics, I believe this session will serve as a forum for sharing our experience and views.

I would like to address a series of questions that will put the process of transition to risk informed regulation into perspective.

1. *Is there sufficient consensus regarding the introduction of risk informed decision making to nuclear safety?*

Nuclear safety, with the protection of public health and safety as its highest priority, is maintained by appropriate decision making, which can become more effective if it is based on valid information about the risk importance of decisions. In order to bring risk informed decision making into nuclear safety, at least three types of consensus are needed: (1) consensus between the operator and the regulator, since the regulatory framework encompasses all of the technical and administrative requirements related to the safety of nuclear installations. This covers the activities of the regulatory body, such as the establishment of requirements, assessment, inspection, enforcement and research and development, and the activities of the licensees, such as the fulfilment of requirements, self-assessment and compliance. (2) Consensus within the regulatory authority. (3) Consensus within the licensee organization.

As an example of what has been accomplished to date in Slovakia, I would mention the major breakthrough made towards risk informed regulation, namely the issuance of Decision-making Act No.1/94, whereby UJD, the Slovak Nuclear Regulatory Authority, committed itself to use the results of a Level 1 probabilistic safety assessment (PSA) in support of safety decisions.

2. *Why are some countries still hesitant to adopt risk informed decision making?*

Perhaps this is because until 1998, PSAs were used primarily to add requirements, and therefore there is still a fear which persists among operators that using PSA will simply lead to supplementary requirements. Unfortunately, there is also a persistent fear on the part of the regulators owing to the recognition of the limitations of PSA (e.g. as to the quality of data, quantification of human error and common cause failures, failure to take account of management/safety aspects, quantification of engineering judgement, and difficulty in ensuring completeness), which lead to an insufficient level of confidence in the results of PSAs.

The experience to date shows that regulators and licensees are quite willing to modify their traditional deterministic approach and improve the efficiency of their analyses by using the insights derived from PSAs. However, such a transition requires a cultural change and a sufficient amount of time, as it presupposes reconsideration of the underpinnings of the entire structure of the regulatory system.

3. *Is risk informed regulation increasing regulatory effectiveness?*

I would say yes, because with regard to the definition of the process, insights derived from PSAs are used in combination with deterministic system analysis to focus licensee and regulatory attention on issues commensurate with their importance to safety. In support of this, I would briefly mention a few examples from Slovakia: we use PSA insights for effective evaluation of alternative safety upgrading measures, demonstration of improvements in plant safety due to extensive plant modifications, effective improvement of plant safety with limited resources and for evaluating and optimizing allowable outage times.

4. *Is risk informed regulation of benefit to utilities?*

Again, I would say yes, because utilities are responsible for nuclear safety and PSA is an important tool for safety assessment. In addition, PSAs can help utilities in optimizing maintenance and surveillance, developing on-line maintenance programmes and optimizing safety improvement programmes. Some instances of risk informed regulation applied in Slovakia are described in further detail in Topical Issue Paper No. 2: Influence of External Factors on Safety.

5. *Are regulators prepared to review PSAs and PSA applications? How much effort is needed?*

This depends greatly on the specific country situation concerning the existing PSA practices, methodology and legislative framework, human resources and the availability of tools and equipment at the regulatory authority. The amount of effort needed for regulators to review PSAs and PSA applications varies from one country to another. Where PSA practices may be weak, a tremendous effort will be required. In order to make full use of PSA applications, the development of PSA quality guidelines is a must.

Another feature of our regulatory authority deserves to be mentioned: since 1997 there exists an independent, analytical group performing internal regulatory reviews at the UJD. This unit has conducted, inter alia, the Chapter 15 Safety Analysis Report (SAR) for the Mochovce nuclear power plant, the Chapter 15 SAR for the Bohunice V1 nuclear power plant, the Level 1 PSA for the Bohunice V1 nuclear power plant and changes to the technical specifications of the Bohunice V1 and Bohunice V2 nuclear power plants. While this independent analytical group is helpful, persistent difficulties remain with human resources. In this connection, human capital is another important issue deserving our attention, as maintaining regulatory competence is one of our primary goals.

I trust that the issues mentioned — which are not easy to address nor quick to resolve — and the difficult process of transition that awaits us, will afford new opportunities for us to further improve our performance.

Lead-in Discussion

PROBABILISTIC SAFETY ASSESSMENTS

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Probabilistic safety assessment (PSA) has been widely used as a risk based tool to support the decision making process more than just for the benefit of risk informed regulation. PSA has been used to determine a plant's safety level, for backfitting and to reduce the unnecessary regulatory burden caused by decisions based on deterministic requirements that lead to insignificant changes on risk monitor parameters (e.g. core damage frequency (CDF)).

There are some cases where deterministic and probabilistic approaches are in conflict and it is indispensable to reconcile them. Some countries solve these conflicts using a case-by-case analysis, while others use conservative solutions. To obtain a general solution for this problem, new standards are necessary that consider when a probabilistic criterion should be used to define, for instance, the redundancy level, test intervals and design requirements. This would contribute to a more comprehensive regulation using both approaches in parallel.

In the early days nuclear safety was defined by deterministic methods, together with operational experience feedback. Probabilistic ideas and methods were used increasingly against very stiff resistance. With time, however, probabilistic safety criteria (PSC) turned out to be indispensable. However, few countries have included PSC within their formal licensing process or standards.

There are different ways of assessing risk using PSC, which are, in numerical terms a reference indication of what is considered acceptable. It is well known that CDF is one of the most reliable parameters to represent the safety of the plant. Reliability goals at system level are useful to trace system performance. In this sense, there is a de facto international consensus to use CDF as PSC, even though there is no common standard utilized by PSA practitioners, there is no uniformity on how to carry out PSAs and there are discrepancies in assigning data values for similar reactor types. In decision making, process reference values for orientation used for each PSA application represent an example of informal PSC.

Performing the PSA of a plant is a difficult process. First, the starting point for an international agreement is the definition of a standard PSA that might vary according to the reactor types considered. In particular, it is necessary to obtain a clear understanding of the meaning and extent of risk comparative parameters (or monitors), such as CDF, large early release frequency or individual dose probability versus CDF. Without a common understanding of these parameters, it will be complicated to define PSC. Second, the establishment of an adequate quality assurance programme for conducting PSA projects on policy and objectives, management control and work implementation is necessary to achieve the desired quality. Third, it is essential to make explicit what impact an uncertainty will lead to in the analysis when PSC are used to decide what is acceptable.

The experience of using PSA considering the three aspects mentioned above would lead to a real agreement on the definition of PSC for different PSA applications, as has happened historically in many technical disciplines. A sufficient legal basis would be established when a standard PSA comes in force in a given country.

On the other hand, nowadays the use of PSA represents a clear understanding between the utilities and the regulatory bodies in many countries. The definition of PSC would improve such an understanding by providing a suitable goal for each PSA application or a better assessment of both the need for or the proposed changes to a plant.

Lead-in Discussion

PROBABILISTIC SAFETY ASSESSMENT AND DEVELOPMENT OF INTERNATIONAL STANDARDS

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In India at present three independent agencies are involved in work related to probabilistic safety assessment (PSA). These are: (a) the utility, which owns and operates the nuclear power plant; (b) an R&D organization that provides technical support to the utility; and (c) the regulatory body. The views of all three agencies have been sought on the issues in question and the responses in the following paragraphs are based on their inputs. The questions are taken from Section 5 of Topical Issue Paper No. 1: Risk Informed Decision Making.

Question No. 8: *Is there sufficient guidance for the preparation of high quality PSAs? Is there a need for an international standard for PSAs?*

The preparation of high quality PSAs needs a well established methodology, state of the art analysis models, reliable and comprehensive failure databases and, above all, trained and experienced personnel. A comprehensive PSA guide should cover all of the above aspects and present ways and means to achieve the goal of a high quality PSA. Currently, several guidelines for the preparation of PSAs are available in the literature and in documents of the IAEA, the United States Nuclear Regulatory Commission and the Electric Power Research Institute. However, these guides are discrete in nature, e.g. guidance is available for a selection of initiating events, fault tree analysis, common cause failure calculation, data analysis, human reliability analysis, etc. A comprehensive document covering all such aspects for all three levels of PSA is required for the PSA community.

There is certainly a need for an international standard on PSAs. This standard should address the requirements of different applications of PSAs and should also take account of different methodologies available for specific aspects of PSAs. A suggestion that would be complementary to preparation of the international standard is to prepare ‘reference’ PSAs for typical nuclear power plants and make them available to all concerned. These PSAs should cover different types of plants such as BWRs, PWRs, PHWRs and WWERs. For each type one should consider an old plant as well as a current state of the art plant during preparation of the PSA. Such reference PSAs can be prepared by international working groups under the auspices of the IAEA.

Question No. 9: *Is PSA methodology sufficiently developed to support 'risk informed' regulation, e.g. treatment of rare events, modelling of human failure, severe accident management, organizational factors? Is PSA methodology sufficiently developed to model new reactor designs that are more dependent on passive safety features?*

The availability of 'high quality' PSAs is a primary requirement for risk informed regulation. Although, in principle, the methodology is sufficiently developed to produce such high quality PSAs, there are limitations in some areas, as indicated below.

For rare events, hypothetical models are used at present. The collection of data on rare events from all countries will be of great help to the PSA team. Human errors are also modelled in PSAs. However, validation of these models involves some amount of subjectivity. Operator performance analysis during actual incidents in plants and the results of simulator exercises are generally used for validating human performance models. The difference in performance shaping factors encountered during simulator exercises and actual incidents introduce uncertainties.

A methodology for modelling organizational factors does not exist and, in our opinion, it should not be modelled. However, good safety culture is another defence, which contributes to enhancing safety. Severe accident management (especially in the public domain) needs a Level 3 PSA study to be conducted, though the uncertainties associated with this are large.

It is believed that the system/component models that are currently being used for reactors are also applicable to new reactor designs that are more dependent on passive features. However, for the generation of adequate, dependable data, substantial efforts are needed. This lack of data puts a constraint on the quality of the results obtained for new reactor designs based on passive features.

Question No. 10: *How is it possible to ensure that operators are in a position to develop, use and maintain living PSAs and risk/safety monitors to support 'risk informed' decisions?*

The operators are generally part of the standard PSA team during the production of PSAs for operating plants. However, since living PSAs and risk monitors are mainly used as operational management tools, the involvement of the end users is essential. Operators' participation in the development and maintenance of PSAs improves the understanding of different aspects of these software packages. Proper training motivates them to use these packages in an effective manner. The user-friendliness of the software packages needs to be ensured and operators have to be trained to use them.

Question No. 11: *What actions should be taken by the IAEA to support the introduction of 'risk informed' decision making, e.g. as related to the areas of the development of international standards, harmonization of criteria, compilation and dissemination of experience, and education and training?*

Development of international standards. The IAEA should develop an international standard for all three levels of PSA. Associated comprehensive guidelines for each of these levels should also be prepared. The preparation of 'reference' PSAs for typical plants (BWRs, PWRs, PHWRs, WWERs) should also be considered. The framework of IAEA co-ordinated projects can be used for this purpose. Experts from interested countries can be involved in the preparation of such PSAs. The IAEA could also promote the idea of a standard software for both the preparation of PSAs and the collection and analysis of failure data.

Harmonization of criteria. Given the present state of a wide variation in PSA quality, methodology, type and design of reactors and such factors as treatment of external events, common cause failures (CCFs) and human error, it is very difficult to harmonize acceptance criteria. However, the IAEA can promote discussion and information exchange in this area.

Compilation and dissemination of experience. The IAEA can arrange to exchange/share information on the following topics:

— reactor specific failure data,
— treatment of CCF in PSA modelling,
— treatment of external events in PSAs,
— data on rare events.

Education and training. The IAEA can assist countries in the preparation and review of PSAs. It can also arrange for formal education, training and certification of PSA professionals.

Topical Issue No. 2

INFLUENCE OF EXTERNAL FACTORS ON SAFETY

(Session 2)

Chairpersons

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Topical Issue Paper No. 2

INFLUENCE OF EXTERNAL FACTORS ON SAFETY

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1. RATIONALE

In recent years a number of worldwide trends have emerged which affect the operating environment of nuclear power plants (NPPs), both externally in the sense of their political and economic business climate, and internally in the sense of their budgets, staffing levels and business practices. It is very clear that the 'span', or breadth, of issues being faced by the owners, operators and regulators of NPPs today, and the speed at which these issues are changing, is much greater than ever before. Included for consideration are:

— Plants under construction or plants for which previously halted construction was resumed;
— Plants operating in a deregulated electricity market;
— Plants being refurbished and restarted;
— Plants undergoing life extension programmes;
— Plants facing closure for political reasons;
— Plants being laid up or decommissioned;
— Plants experiencing changes in ownership or operating control even by non-nuclear organizations;
— Plants which need substantial design and material condition upgrades;
— Plants facing a significant decline in revenue or funding;
— Plants with staff learning new management techniques;
— Plants engaged in new regimes of safety regulation;
— Plants with serious shortages of human experience and talent;
— Plants facing ageing issues (institutional, personnel and equipment).

What is particularly new is that many of these activities are now often going on simultaneously within a single utility. This means that the management attention span may be substantially stretched. In the USA, in particular, many of these issues have been present for several years. They began before economic deregulation of the electricity industry, and their frequency and significance have generally increased in recent years as a result of deregulation.

It is of paramount importance that co-operation and learning be promoted extensively as the industry faces these multiple overlapping and potentially distracting challenges. The basic principles of safety management that have been established and upheld in the past are extremely relevant for the future, but they have to be applied to new circumstances, and in some cases by new players. This challenge is not simply directed at the management teams of the NPPs. Instead, governments, regulators, owners, operators and staff all have a role to play in ensuring that the major upheavals that are taking place are dealt with safely and successfully, while taking full advantage of the positive incentives and opportunities offered by these challenges.

2. STATUS OF THE TOPICAL ISSUE

2.1. STATUS

The single most important change is the move to make electricity (and therefore nuclear electricity) a simple commodity in a commodity market. This change is accompanying electricity marketplace deregulation or rationalization in a number of countries, with varying degrees of success.

The second (possibly related) change is to shift nuclear power from 'government protection' to 'stakeholder influence'. This trend is driving a number of early plant closures, either due to identified problems, or as a result of political decisions. Early closures create substantial problems for staff motivation and skill retention: decommissioning plans must be prepared, financial support obtained, licensing and waste management issues resolved and the public and local governments kept informed, all while safe operation is maintained.

Thirdly, there are issues that emerge from the maturing of the industry. These include technical issues such as equipment degradation, but also the supply of skilled, competent staff for the future. This issue is currently a significant threat on the horizon of the nuclear industry.

Finally, these trends are posing new challenges for nuclear safety regulators, and there is, therefore, growing activity in the area of matching the regulations to the issues and problems that are emerging.

2.2. RESPONSES

The industry is responding to these trends by continuing its tradition of sharing information and experience, although this could be threatened in some competitive situations. Progress has been made in developing approaches to a number of these issues. Some examples are given in the following pages.

2.2.1. Deregulation

There is significant experience in the UK, USA and a limited number of other European countries about the impact both positive and negative of deregulation of the electrical supply industry on power plant operations. A report on deregulation from the perspective of the regulatory community is being prepared by the OECD Nuclear Energy Agency (OECD NEA) (currently in draft form) [1], and has been used to assist with this review.

2.2.2. Early closures

The closure of nuclear generation facilities before the end of their design life due to cost or performance related decisions, or decisions of a purely political nature, is being experienced in many countries. A recent IAEA workshop, entitled "Managing the Early Termination of NPP Operations" [2], addressed this issue. Attended by participants from North America, and Eastern and Western Europe, the workshop concluded that there are no internationally accepted common approaches or guidelines to help the utility or regulator on what to do and how to plan under these circumstances. It was also concluded that the IAEA would be an ideal forum to develop this guidance.

2.2.3. The nuclear industry and workforce

With the maturing of the technology, the lack of growth in the nuclear industry in many States and the demographics created by early expansion in the 1970s and 1980s, many experienced people are retiring from the workforce and little new talent is being attracted to take their place. Together with this, many plants are approaching the end of their design life and while many operators are engaged in life extension activities, others are intending to phase out their older plants without replacement.

The IAEA has sponsored exchanges on the problems associated with staffing, and the subject of knowledge retention is becoming an area of attention. Technical information exchange is also ongoing on issues of plant ageing [3] and decommissioning.

3. PROBLEMS IDENTIFIED AND ISSUES TO BE RESOLVED

3.1. DEREGULATION AND COMPETITION

Electricity is increasingly a competitive commodity business. Governments are deregulating the electricity supply industry, introducing competitive markets and selling or combining assets.

3.1.1. Background

The trend towards deregulated and competitive marketplaces is spreading into the electricity sector. There have been successful transitions of the electricity markets and successful transfers of the ownership of NPPs (private sales, leases or transfers of operating licenses), as well as strategic partnerships and alliances, but there have also been significant difficulties in some areas. A large number of the world's NPPs are either experiencing, or know that they will experience, these changes in the next five years.

The following are some general observations about this trend:

— It is altering the governance structure of NPPs in some countries or utilities and is bringing in new players: new regulators, new managers, new shareholders, new market-makers, etc. Many of these players have had little or no prior direct exposure to the operation of NPPs and the necessary overriding focus on nuclear safety.
— It places increased attention on the financial performance of NPPs. This means that asset values (material condition), operating performance, reliability and costs are very heavily scrutinized and managed.
— It drives a move towards 'plan the work and work the plan' in almost every area (e.g. ensuring that outage performance is on scope, schedule and budget, that costs are managed to budget, and that planned capital investments to upgrade the plant are spent on time and on budget).
— It can alter some very long-standing features of the operating environment such as grid supply security to the NPPs, and the basic market framework (i.e. whether an NPP has a 'right to supply', and possibly forcing consideration of unit manoeuvring).
— It provides a valuable opportunity to make other linked or parallel changes that decision makers wish to adopt.

Obviously, not all NPPs are experiencing all the changes that deregulation and/or privatization are bringing. However, the broad effects are widespread.

3.1.2. Problems and issues

Many of the changes are taking place in the area of governance. Some nuclear plants are becoming just business assets in the portfolio of an organization. Frequent changes are occurring in the ownership of utilities and in the type of businesses that the utilities are operating. There are also frequent changes in the management of NPPs; in many cases the top level managers have little nuclear acumen, expertise or experience. There has been an increase in the practice of acquisition and disposal of assets by companies, both nationally and internationally. This in turn is leading in some countries to a new situation in which the owner and the operator of an NPP may not be the same. This type of separation can impact on licensing arrangements, which may have in-built assumptions that the owner is the operator. (The experience in the USA has been that although owners and operators are often not the same, they are typically affiliated companies.)

The overall trend is therefore one of introducing new owners, new management practices, and new geographical relationships. In these new configurations, top management is business (financially) focused because financial performance and credibility are vital to shareholders and investors.

New marketplace (competition) regulation and practices have the goal of providing a 'level playing field' for access to the grid. They are not directed at nuclear safety. This is having a direct impact on operations. Along with the potential threat to the 'right to supply', which could initiate forced shutdowns, there are potential impacts on the reliability of grid supplies to NPPs for safety support as the grid is operated in different modes for competition. There are substantial financial pressures and penalties to meet committed generation targets (outage dates, manoeuvring rates, etc.) and there can be other impacts such as decisions about longer term maintenance investment. The cost reduction pressures are relentless and plant managers can easily become distracted from operational safety by these many new issues.

In response, utilities are reorganizing, downsizing and using more contracted services (some of which are closer than before to the 'core' functions of the plant). These contractors may be selected on the basis of the lowest bid and may have less qualified staff and experience than the traditional repeat or partnership contractor. There could be staff from many different organizations working on the site and the operator's resources may have difficulty in effectively controlling the contractor's work. Simultaneously, there is inevitable production pressure. This is not intrinsically bad — NPPs exist to produce power — but it has to be managed in ways that enhance human performance and the plant condition rather than detract from it. In particular, management must strengthen conservative decision making practices to avoid degradation, and it must ensure that competition does not inhibit the free sharing of information between plants, and degrade safety through loss of good operating experience (OPEX) exchange.

As the stakeholders look ahead in this new environment, they have to examine consumer trends, social concerns and political perspectives because these will affect future investment (distributed generation, environmental impact perception, etc.). These trends and perspectives also affect investment in the existing plant, and at some stage may drive decisions on the part of plant owners to move out of the nuclear business. This situation can create uncertainty and distraction for plant staff from safe operation.

Maintaining nuclear utility share prices and financial returns will become increasingly critical as nuclear comes to be regarded as purely a business asset. These business results can be drastically affected by adverse performance reports. There is, therefore, the potential for the business to become less transparent and less likely to make performance evaluations public, which can contribute to an erosion in public and regulatory confidence.

There are some indications that due to competition and shareholder sensitivities, the willingness to share safety and performance information may be decreasing. The challenge to the industry is to continue to be as open and transparent as in the past despite the changing business conditions.

3.1.3. Opportunities

It is important to recognize, in the midst of all this change, that there is a substantial opportunity to confront realities and to change them for the better. Poorly performing plants can be identified and upgraded or shut down. People can be freshly motivated and better managed, and new ownership and new perspectives can give positive energy to a maturing industry. To achieve these benefits is a substantial and imperative management challenge which has, in some countries, been successful in producing substantive safety and economic benefits.

A particular opportunity is to enhance human performance. ‘Event-free operation’ (i.e. high standards of human performance and reliability of equipment) enhances asset value and production revenues, while reducing costs and improving public and regulatory confidence in the operation. Alongside this there is the possibility of introducing new reward systems. However, these must be properly geared to the desired behaviour for safe operation.

There is also a renewed emphasis on forward planning in all areas (outages, plant life assurance upgrades, staffing, budgeting, etc.). Management will, therefore, focus on forward planning and adherence to plan (‘Plan the work and work the plan’) in all areas, and this has real benefits to safety if plans are properly conceived, are of high quality and are implemented effectively.

Freeing utilities from the bounds of State control can unleash opportunities for continuous improvement in the safe operation of nuclear facilities. The combination of attitudinal changes towards more innovation, greater management and organizational flexibility, and an increased array of tools for managing change can stimulate increasingly higher levels of safe, reliable and competitive performance.

3.2. POLITICAL AND ECONOMIC ENVIRONMENTS

Nuclear power is being shifted out of ‘government protection’ into ‘stakeholder influence’. The political and economic environment for NPPs is therefore shifting significantly in some States, to the extent that the operating environment of financial or other support is radically altered. For example, in some countries there is pressure to shut down even safety upgraded plants as a precondition to joining the European Union, and in others the pressure of minority groups within government coalitions is sufficient to force policy reversals regarding nuclear energy.

3.2.1. Background

In many countries nuclear power started life as a ‘protected’ business in the sense that governments provided substantial resources and also, perhaps, protected markets and prices. Governments have also defended the industry against its critics and have been heavily involved in direct regulation (nuclear safety) and other regulation (e.g. environmental), all of which have affected the industry’s operating climate.

In some countries, therefore, the operation of NPPs has become a highly charged political issue, since stakeholders believe that the way to change the industry is through political activism to influence governments. This leads to situations where governments become reactive to political pressure. In other cases governments are changing their agendas and are starting to place other objectives ahead of the protection of the nuclear industry (e.g. opening the electricity market to competition, or de-activation of the industry to address social or political concerns), and are, therefore, proactively promoting change in the operating environment.

Finally, in some countries there are programmes of growth, with NPPs under construction or being refurbished to extend their operating life.

3.2.2. Problems and issues

In some countries there are politically driven demands or decisions for early plant closures. These create instability and uncertainty for operating staff, with a possible loss of focus on safety. These demands are challenging to manage as they raise issues of; staff motivation and maintaining a good safety culture, personnel management, decommissioning, finances, licensing, waste management and public relations all at the same time that the plant is trying to maintain high levels of safety.

There are other cases where the desire to achieve fully commercial rates of return on assets is driving substantial and rapid cost reductions. If these cannot be achieved, then the plants will also face closure, with the same range of issues mentioned above.

Substantial uncertainty, insecurity and distraction can be created in operating staff by the unstable or shifting external environment. In addition, NPP management can become ‘helpless’ in the face of imposed change, and consequently lose decisiveness, energy and authority in the internal management of the plant. Unsettled and distracted staff can threaten a proper safety focus either by becoming disillusioned and demotivated, or by becoming excessively focused on production, which they may see as the key to their security. This in turn could inhibit the reporting of adverse conditions due to staff concern that the plants must appear to be performing well, and could threaten a good questioning attitude, which is a component of a healthy safety culture. The need to maintain worker motivation under all circumstances, by creating confidence that there is a future in the business for everyone, becomes a significant issue under the threat of closure and financial difficulties.

Utility finances are unstable in some countries (e.g. payments are not being made for electricity production due to political/economic instability and the essential service nature of the product). In these cases there is extreme pressure on financial investment and impacts on staff through low wages or non-payment of wages. Similarly, regulators in many countries, often being under government pay rates, offer significantly lower salaries than utilities, with subsequent difficulty in attracting and holding new talent.

Less acute, but significant in the longer term, are issues surrounding the predictability of the economics of operating nuclear plants. Environmental perspectives and future changes to regulation are affecting the views that investors and shareholders have of the future of the industry.

Overall, the issues surrounding the operating environment of NPPs have broadened substantially, but follow one general trend — they are being brought out of ‘government protection’ and into ‘stakeholder influence’. This is happening in different ways, at different rates and with different stakeholders involved. Sometimes the transition is carefully managed to avoid potentially damaging ‘transients’, but in other cases NPPs are being faced with radical changes, as they have to adapt to some new realities very quickly.

A clear priority in responding to major external change is open and frequent two way communication regarding these matters with employees, the regulator and the public. Simply knowing the directions and possible and probable outcomes can make a substantial difference to the human reaction to change.

3.2.3. Opportunities

Another trend is to produce greater accountability to stakeholders, so where there are clear stakeholder roles and effective communication and management of change there can be positive outcomes for ensuring proper plant condition and human performance. The US nuclear industry has clearly demonstrated this potential over the last five years.

The premature closure of some plants has been used as a lever to bring into public, business and environmental focus the positive aspects of nuclear power generation. An industry opportunity exists here to capitalize on this aspect in public and political forums to illustrate the role nuclear power can play in the future energy supply mix, considering the dearth of present practical and sensible alternatives.

The political and economic pressure in some countries, which is stifling the growth of the industry, may at the same time stimulate the life extension of some plants. This, coupled with the achievement of fully commercial rates of return from the safe operation of some NPPs, is causing businesses and governments to reconsider the use of nuclear energy for potential long term financial returns and stability of clean energy supply. This in turn is forcing an innovative look at the technology in order to develop an NPP design more acceptable to the public and business from both the safety and economic viewpoints.

The continued expansion of the industry in some countries is a constant reminder to the global energy sector of the viability of the technology and of its capability to design, build and operate safe plants in the future.

3.3. THE CHANGING INDUSTRY

The nuclear generation industry is maturing, and this brings new challenges that have to be managed alongside the mainstream operations. Examples are:

— *Securing qualified human resources for the future;*
— *Managing ageing plants;*
— *Upgrading plants for life extension;*
— *Decommissioning activities, including on-site storage facilities.*

3.3.1. Background

The two general challenges posed by changes in the industry are caused by actual or potential mismatches of resources to needs. The first mismatch is that just as the management and operational issues are proliferating, the pool of experienced human talent is under threat of a decline. The second is that the nature of NPP technical problems is changing (condition monitoring, life extension, decommissioning, on-site storage requirements, etc.), while simultaneously the technical infrastructure (R&D, original equipment supplier expertise, etc.) is eroding through staff retirements, lack of an ongoing new construction programme in some countries, reduced demand from operating organizations and reduced funding from governments.

These two mismatches, or ‘paradoxes’, are complicating the management challenge of maintaining and enhancing safety through changing times. The problem with these paradoxes is that they are not always being actively controlled by corporate level decision makers, and indeed there are limits on their level of control of many of these factors. Yet, they can be very limiting or threatening to management at the plant level.

3.3.2. Problems and issues

Broadly speaking this trend is slow, insidious and hard to assess in terms of the safety impact. Yet, on the overall scale of issues facing NPPs, it can sometimes be the most serious threat to safety because competent people and a sound technical condition of the plant are the two foundation stones for everything else.

Some utilities definitely face an ‘experience crisis’ due to adverse demographics. This has likely been driven by the fact that downsizing simultaneously often loses both the most experienced talent and the younger talent pool. At the same time there are problems attracting new entrants. The overall image of the industry, its largely bureaucratic organizational work practices (which under a competitive environment are showing signs of improvement) and uncertainty over its long term future can all conspire to make it relatively unattractive to younger people. In addition, in the face of a lack of interest from students, many universities and colleges are no longer teaching nuclear technology.

The loss of institutional memory (‘why we do things…’, etc.) due to staff reductions and retirements can have a serious impact on management’s overall ability to sustain and enhance safety in changing times. It can be very difficult to spot a significant degradation in this area because it happens slowly, and because once memory or capability is lost, there is no one left to recognize that fact.

There may be insufficient resources available to examine the technical issues facing some utilities. Ageing plants can create technical situations that threaten the design basis. These can go unrecognized, or they can be costly to address, causing a challenge to the plant owners and managers. In some countries, national solutions to waste handling and spent fuel storage are not being addressed in a timely manner, thereby forcing the need for on-site storage considerations in excess of original design intentions.

Additional work is required to upgrade plants for life extension. Data must be collected and analysed to demonstrate that the plant safety systems will continue to meet their design intent under emergency conditions. Also, because of the demands of more refined analytical techniques, backfits may be required to mitigate newly discovered circumstances.

Decommissioning is a long and costly process for which few international guidelines have yet been developed. Utilities facing this circumstance, therefore, tend to produce their own unique programmes which can be expensive, labour intensive and potentially hazardous.

3.3.3. Opportunities

The potential of many existing NPPs for significant life extension is certainly capturing the imagination and investment of the business community. The management and execution of this process is a potential rejuvenator throughout the nuclear community as it offers secure long term prospects.

There may be the opportunity to bring in significant numbers of new staff to learn new methods and behaviour and refresh the culture of the operating plants. The challenge is to be innovative in developing ways to attract the new staff.

New solutions to spent fuel storage and waste handling are also being sought.

Mergers and acquisitions amongst nuclear utilities may encourage economies of scale and thus, to some extent, mitigate the loss of experienced people. Thus, technical expertise in areas such as refuelling outage management and support engineering may be able to be spread over a broader base without adverse impacts in those companies with several units.

The use of new technologies, in the technical area as well as in the human performance and management fields, is an opportunity to attract new and innovative staff. The technology, though yet to be fully developed for decommissioning, has potential applications in other industries that deal with hazardous by-products.

Also, in some cases significant fresh investment is being made to upgrade the safety and reliability performance of NPPs in order to extend the lifetime of a plant when justified from an economic perspective.

3.4. REGULATORY ENVIRONMENTS

As the operating environment of NPPs changes, the regulatory framework is either shifting in response, or failing to shift in response. In either case, there is an impact on both regulators and operators as the previously established 'match' between operations and regulation is being disturbed.

3.4.1. Background

Nuclear regulators are being forced to understand and react to the shifts that are taking place in the operating environments of NPPs. This is broadening their areas of interest and insight. Where they consider it appropriate, they are changing the regulations and introducing new methods and practices for oversight and enforcement. Both operators and regulators are therefore adapting, or struggling to adapt, to new realities. These changes can be expected to produce parallel changes in their relationship, which then becomes a secondary but equally important factor in the overall management of the facility and its safety.

In general, the shifts in regulatory attention and workload can be characterized as follows:

- — Governance of NPPs: Changes in ownership, operating control, competitive marketplaces, financial guarantees for decommissioning, etc.
- — Safety management and performance in NPP operation: New management practices, altered operation and management (O&M) budgets, grid reliability in deregulated markets, use of contractors, remove or return plants to service, etc.
- — Specific changes introduced by, or directly impacting, regulators: New legislation, adoption of new standards or methodologies of oversight such as performance

and process based regulation and risk informed assessments, new approaches to enforcement and the consequential potential decisions on the requirements for backfitting of safety upgrades, changes in funding for regulatory agencies, etc. Regulators do not always introduce these changes themselves. Sometimes they are imposed on them by the government.

— Concern over the issues raised as the nuclear power industry matures: Physical ageing of components, R&D expenditures, management, storage and disposal of high level radioactive wastes and spent fuel, the supply of sufficient human talent for the long term, the development and maintenance of good safety culture within the operating organization, etc.
— Management of the relationship between NPP owner/operators and the regulator.
— International issues such as the Convention on Nuclear Safety, common technical standards, and co-operation and public relations.

Regulators are especially sensitive in ensuring that their actions or capabilities have positive impacts on safety. However, their impact is rarely entirely controllable from within. It is the combination of the regulator/licensee relationship and the framework that actually enhances or degrades safety.

3.4.2. Problems and issues

Taken together, the effects of this trend represent a major conceptual, managerial and administrative challenge for regulators, who are experiencing pressure to address significant numbers of new or emergent issues simultaneously. This is placing substantial pressure on their resources. Regulatory staff may lack the knowledge or resource capability to monitor, anticipate and manage the wide range of new and emerging issues, and this could lead to a loss of focus on operational safety. In some countries all this is happening while government funding to nuclear regulators is under review or is being reduced. This may lead to a reduction in the ability of the regulatory body to detect degradation in safety management before it reaches the performance stage, and may also inhibit the regulators' ability to exert influence at the senior management level in detecting such shortfalls.

The overall programme of change is largely being driven by governments, markets and NPP owners. Regulators are, therefore, often being placed in a position of being reactive to change, and this can lead to a loss of clear vision and direction. In these circumstances, existing regulations may appear to be mismatched to the emerging operating environments, and yet it is not easy to decide how and when to create new regulations. The regulator may decide to intervene in NPP management practices with insufficient insight or experience to produce the desired positive results, or regulatory questioning could distract NPP management in an already overstretched situation.

In a more competitive world, good commercial performance means removing all unnecessary costs and operating more efficiently and effectively, and also safely. The regulator may feel the need to react to this drive by ‘compensating’ with greater and greater levels of oversight and intrusion. Paradoxically, this may also so deflect the NPP from its prime focus (and from its ability to deliver improved performance safely) that its commercial performance actually suffers. That in turn may tend to degrade the safety performance that both the NPP and the regulator wish to see improve. The regulatory staff can also become unsettled and distracted due to internal organizational change and the impact of external pressures.

Another factor is that there is a trend towards regulatory agencies recovering their costs from the licensees, which, if ‘micro-managed’, very easily leads to a lot of debate between NPP owner/operators and the regulator, and further ties up resources.

The nature of the regulations may be changing as new areas (e.g. environmental impacts) are being addressed, new overall perspectives such as moving from prescriptive to performance and/or process based regulation are being introduced and new standards are set. Sometimes there are interface issues, for example, environmental regulation is often the responsibility of other government agencies. These in turn can negatively affect the operator. In some countries, new initiatives involving risk informed approaches form the basis for licensing and inspection regimes, which were formerly deterministically based. Some regulators now impose specific requirements on the licensee to demonstrate that there will be no detrimental effects on safety prior to making organizational changes.

There is also the risk of the regulators becoming isolated from utilities. Excessive legalism could appear in the relationship, and open communications could be negatively impacted.

3.4.3. Opportunities

As the industry changes and evolves towards an economically driven business, as a result of the previously described changes, so comes the opportunity for the regulator to shift from prescriptive regulation and/or performance monitoring to include more process evaluation and risk informed approaches where risk evaluation and consideration is built into the decision making processes. This is supportive of the industry insofar as it would generally place a lower financial and operational burden on NPPs while ensuring that safety standards are maintained.

There is an opportunity to rethink and redesign the role of the regulator and the nature of the regulation (e.g. standards) as the industry changes. Also, in some countries there will be the opportunity to separate the control of the regulator from the control of the utility, which is, for example, a requirement of the Convention on Nuclear Safety and is mentioned in IAEA standards.

As a result of shareholder sensitivity to potential reports of declining performance and the consequent potential trend of the licensee to be more secretive with such reports, the regulator may have to develop measures of performance which are completely transparent to the public. These could take the form of red/green rankings or test reports similar to those used in the consumer industry. The NRC practice of displaying plant safety performance indicators on the Internet is a good example of such a practice.

Coupled with this is a unique opportunity to improve public confidence in the nuclear industry as a whole. As changes evolve, the owner/operator and the regulator can manage the process with a high degree of transparency and public involvement, using much improved communication tools. This transparency can be transformed into a learning environment for public acceptance and trust of the industry as a business.

4. RECOMMENDATIONS FOR STRATEGIC ACTIONS/PRIORITIES FOR FUTURE WORK

4.1. SUPPORT FOR SAFETY CULTURE PRINCIPLES

In this time of substantial change and future challenge, it is important that the principles of effective safety management be reinforced. The concept of ‘safety culture’ has been emphasized in order to recognize that in matters of nuclear safety ‘everything matters’. A number of organizations operating NPPs have not, however, fully embraced the concepts of safety culture at a corporate policy level. However, this is an ideal time to move that process ahead, and the IAEA could take a leading role, along with other international organizations such as the World Association of Nuclear Operators (WANO) and the OECD NEA, in facilitating the process of understanding and building global commitment to safety culture principles.

4.2. INFRASTRUCTURE SUPPORT

Under the Convention on Nuclear Safety, signatory States have a responsibility to support the infrastructure necessary for nuclear safety. This includes ensuring that adequate financial resources are available to support each nuclear installation throughout its life, and also includes ensuring that a sufficient number of qualified staff with appropriate education and training is available.

These obligations have largely been established through licensing requirements placed on licensees. However, as governments introduce new operating environments through such activities as market deregulation, early plant closures and economic restructuring, the ability of the licensee alone to meet these requirements can be compromised. This may call for a fresh look at how the entire industry is being steered by the combination of accountable stakeholders (governments, owners, operators and regulators).

In some countries, the technical R&D support for the nuclear power industry has been largely government funded. This support may be shifting due to changes in the industry, but new issues related to ageing, decommissioning and waste storage are still emerging and require attention.

The IAEA, along with other organizations such as the OECD NEA, can take a role in facilitating broad spectrum reviews of the issues surrounding infrastructure support in a changing environment.

4.3. STRONG LEADERSHIP

The greatest degree of accountability for nuclear safety still falls on the plant management. There are many industry and IAEA programmes for exchange and for peer review of management and leadership practices. These need to be fully supported and strengthened as the industry moves ahead, and the openness and transparency of the industry to the public must be encouraged despite possible business pressures to do otherwise. Again, the IAEA is able to support the required exchanges and to facilitate the development of guidance documents.

4.4. CO-OPERATION

There could be a tendency for the industry to fragment as it deals with differing challenges. However, it is still very much a business where a safety incident anywhere is an issue for everyone involved. Some plants are still in need of significant financial and other support from sources outside their direct control. There need to be mechanisms whereby this support can be requested and provided.

4.5. EFFECTIVE REGULATION

The nature of regulation has a significant impact on safety issues, and on management practices. The trends that have been discussed are having a significant impact on regulatory agencies, and there is a particular need for co-operation and exchange as they set new directions for the future. The IAEA, along with other organizations such as the OECD NEA, should continue to provide forums for regulators to share their insights and experience.

4.6. IMPORTANCE OF COMMUNICATION

It is crucial during times of change that communications between the industry and regulator be open and transparent and that processes be in place to ensure that this occurs. Communication between utilities, the public and the media is to be encouraged to counter the public perception that it does not have a need to know about nuclear matters and safety.

4.7. ROLE OF THE IAEA

The mission of the IAEA is to assist Member States in the safe operation of NPPs and in meeting the challenges of the new business environment. In co-operation with other international organizations such as WANO and the OECD NEA, the IAEA can support the safety of NPPs by identifying the key issues confronting stakeholders, providing guidance on effective practices, providing forums for utilities, regulators and governments to consider their directions, providing support for safety in their decision making processes, and sharing insights and experiences. Also, it can provide safety related services such as operational safety reviews (OSART), international regulatory reviews (IRRT) and operating experience and safety culture enhancement support.

5. QUESTIONS TO THE CONFERENCE

(1) What are the most effective methods of maintaining safety during times of externally imposed change, as is presently being experienced? The concept of good management of safety and safety culture is being promoted by the IAEA as one answer to sustain continuous improvements in safety and performance standards under such conditions. Is this approach in fact effective and sustainable? What are its vulnerabilities and how can they be removed?

(2) How can the nuclear industry attract new talent to effectively halt the loss of expertise as a result of retirements and downsizing? What is the role of the IAEA in this challenge?

(3) What is needed to assist the industry in establishing consistently safe, effective, efficient and cost effective decommissioning programmes? Would the IAEA's help be useful in this area and, if so, what kind of priority should it be given?

(4) Some regulators are changing their regulatory strategy from the prescriptive approach, through results based, to process oriented methods. This is, in part, dependent on the maturity of the regulator and the licensees, but such a trend would assist the nuclear industry in facing future challenges as it tends to be less intrusive and burdensome on the industry. Is this a direction suitable for all regulators to follow? And is the potential risk of licensees not fully understanding the nature of this new enviroment, and allowing safety margins to possibly decrease under competing pressures for increased production, acceptable?

(5) The IAEA and other organizations such as WANO rely heavily on the dissemination of technology and information between utilities in order to promote improved performance. What strategies should be adopted by the IAEA in order to ensure that this information exchange between nuclear utilities is not stifled by competitive pressures?

(6) Nuclear power presently supplies 16% of the world's electricity. Nuclear power plant safety and performance have improved dramatically in the last ten years, and in some countries excellent environmental and business results are also being achieved. The political decisions for the premature shutdown of some plants is, in some cases, highlighting the lack of viable alternative sources of power. How effectively is this being broadcast to the public, political and business community? Is there a role for the IAEA in this effort?

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Power Plant Ageing Management Programme, Safety Reports Series No. 15, IAEA, Vienna (1999).

[2] Managing the Early Termination of Nuclear Power Plant Operation (Proc. Workshop Greifswald, 2000), IAEA, Vienna, (2000).

[3] OECD NUCLEAR ENERGY AGENCY, Nuclear Regulatory Perspective on Deregulation of the Electrical Supply Industry, draft report, OECD, Paris.

Keynote Paper

MEETING THE CHALLENGES TO NUCLEAR SAFETY OF PHASING OUT THE COMMERCIAL USE OF NUCLEAR POWER IN GERMANY

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Abstract

MEETING THE CHALLENGES TO NUCLEAR SAFETY OF PHASING OUT THE COMMERCIAL USE OF NUCLEAR POWER IN GERMANY.

The decision of the German Government to phase out nuclear power is based on the nuclear and radiation risks that inevitably are associated with the operation of nuclear power plants. These risks are socially not accepted. The nuclear sector in Germany has therefore been affected since more than a decade by the erosion of the staffing, technical and knowledge bases. The consensus based phase out policy is an efficient approach to cope with these and other internationally discussed external factors challenging nuclear safety. The further use of nuclear power is limited and can be adapted to the availability of needed infrastructure. During phasing out, safety has to be maintained and improved in accordance with the law. To this end, the German nuclear regulatory body has taken the following actions that are also described in the paper: (i) regulatory approaches to power operators' organizational changes and staff development; (ii) establishment of a safety culture, safety management systems and performance indicators; (iii) modernization of the safety related regulations to the current state of the art in science and technology; (iv) maintenance of strong nuclear regulatory supervision and effective periodic safety reviews; (v) measures to preserve competence and infrastructure for the plants' residual operating lives and for overcoming the consequences of the use of nuclear power.

1. INTRODUCTION

Concerns have been raised that the policy of the German Government to phase out the commercial use of nuclear power could significantly add to the external factors challenging both nuclear safety and nuclear safety regulators [1]. However, it can be stated that:

— The German phase out will not create any new external factors. The external factors and related safety challenges to be addressed in Germany today are similar to the issues discussed in the paper for this topical issue or in recent publications by the IAEA, the OECD Nuclear Energy Agency or the institutions of the European Union.

— The German phase out policy, which is a consensus approach to end the commercial use of nuclear power in an orderly fashion, provides a pragmatic framework and time schedule to meet the challenges created by the external factors.

Contrary to many other regulatory authorities, the BMU (the Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit or, in English, the Federal Ministry for the Environment, Nature Conservation and Reactor Safety), especially its General Directorate of Nuclear Safety, which is the supreme regulatory authority in Germany, has two basic functions. Firstly, the BMU is responsible for the development of the legal basis for the use of nuclear power in Germany. In this connection it has to prepare (in co-operation with other ministries) a draft law for the phase out, which is to be submitted to Parliament for its final decision. Secondly, the BMU is responsible for the typical functions of a nuclear safety regulator and for the supervision of the respective regulatory authorities of the Länder (Federal States) that enforce nuclear legislation on behalf of the Federal Government (Fig. 1).

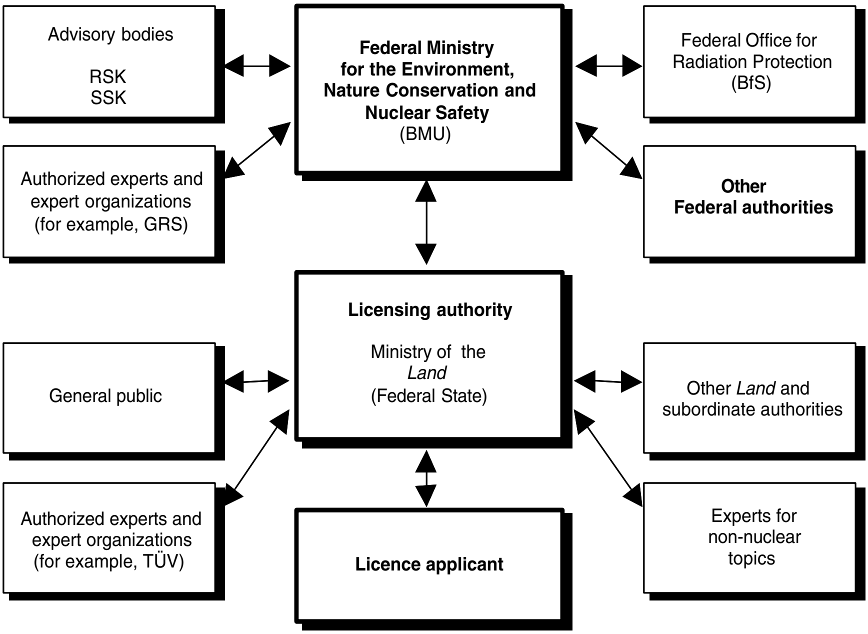

FIG. 1. Nuclear regulatory bodies in Germany and participants in regulatory procedures.

2. BOUNDARY CONDITIONS AND SAFETY CHALLENGES DURING THE PHASE OUT

2.1. Past developments and current status

In the past, Germany has experienced the same expansion and subsequent decline of its nuclear programme as have many other countries: the need and potential benefits of nuclear power were overestimated, while the problems and costs involved in resolving the safety and waste management issues, as well as public opposition, were significantly underestimated. Currently in Germany there are 19 operating nuclear power plants, which contribute about one third of the electricity supply; 16 plants have, however, already been shut down (Fig. 2). Applications for the final shutdown and decommissioning of two further plants, one of which is still operating, are in progress. Thus, the past nuclear developments and uses in Germany have created a legacy of installations that need to be decommissioned and of nuclear wastes that need to be stored, treated and disposed of safely by applying state of the art safety requirements and regulatory procedures. The main steps to dispose of these legacies safely will take three to four decades, and will require a lot of money as well as competent organizations and industries.

There are significant signs that the necessary expertise and infrastructure to fulfil these difficult tasks are in decline and might before long become insufficient. The future availability of nuclear experts within the industry, regulatory bodies and expert and research organizations, and the capabilities of universities and the number of students following nuclear related courses, have been analysed in detail and can be summarized by the conclusion: “Phase out of nuclear power at German universities and research centres ahead of schedule” [2]. The lack of acceptance not only by the public, but also by the scientific–technical community is the key weakness of nuclear power.

Cost pressures and the long standing stagnation of the nuclear field have already led to a halt in production in nuclear manufacturing and supply industries, which is increasingly affecting plant operations. There is a real and imminent danger that there will be competence and supply gaps in some key areas [3], which may result in serious shortages of time critical equipment, for example with respect to core instrumentation, reactor protection, control rod drives or reactor pressure vessel internals. The plant vendor has already reduced staff numbers in some specialist areas to critical competence levels; it is feared that the remaining volume of orders will not be enough to keep up, in the long term, even this minimum level. Currently, negotiations are taking place on how a cut in the number of specialists in critical disciplines can be avoided.

There also exist similar problems in the supply industry. Qualified manufacturers are becoming rare, particularly in the area of instrumentation and control

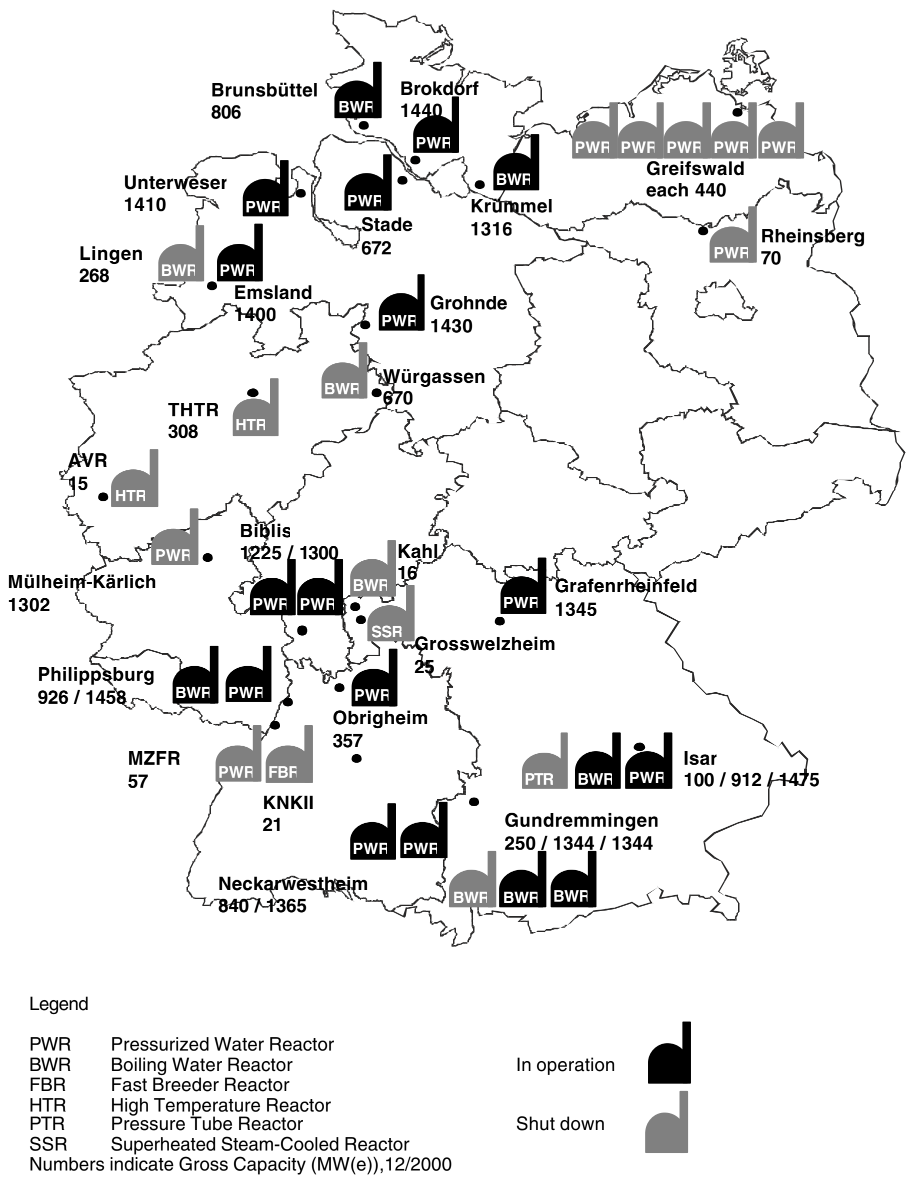

FIG. 2. Nuclear power plants in Germany.

regarding, for example, measuring instruments (i.e. plant equipment that has a lifetime of approximately 10–15 years). It is hence becoming increasingly necessary to prepare individual specifications for some equipment. In some cases the utilities have built up their own repair and manufacturing capacities.

The nuclear sector in Germany has already been affected for a decade by the erosion of the staffing, technical and knowledge bases that are necessary for the safe and profitable operation of plants, as well as for the orderly overcoming of the burdens in the fields of decommissioning and disposal. Governments only have limited means to care for sufficient experts and students or companies in the nuclear sector. These developments therefore need a major policy response by the Government as well as by industry in their primary responsibility for nuclear safety (Fig. 3).

This policy response has to take into account that the commercial use of nuclear power is inevitably associated with specific risks. These low probability but high consequence risks of nuclear accidents occurring is not accepted by the public in Germany. The current Federal Government is convinced that there is no need, and therefore no justification, to take these risks and therefore the risks that are currently being taken should only continue for a limited period. It has been decided that the future energy supply must come from safe and sustainable alternatives. The Federal Government has, therefore, decided that there will be a well ordered withdrawal from commercial nuclear power utilization by limiting operations in an economically acceptable way. This is regarded as an adequate policy to respond also to the current safety challenges from external factors.

2.2. Elements of the consensus on phasing out nuclear power

After a year and a half of very difficult negotiations on the phase out of nuclear power with the large German energy utilities, an agreement was finally reached on 14 June 2000 [4]. Further negotiations were necessary before this agreement could be signed on 11 June 2001. The resulting consensus with the industry can avoid legal conflicts with the nuclear plant operators. All the parties involved have clear boundary conditions, with political and legal support for the remaining operational life of the nuclear power plants and for the resolution of safety, decommissioning and waste management issues. Based on the Consensus Agreement and on an agreement with the other ministries, a revised version of the Atomic Energy Act has been drafted by the BMU [5]. At present, the BMU is in the middle of the implementation phase. It is expected that the new law will enter into force in the first half of 2002. The fundamental cornerstones of the Consensus Agreement are that:

— The electricity volume for each power plant will be restricted so that a plant under normal circumstances will have an operating life limited to 32 calendar

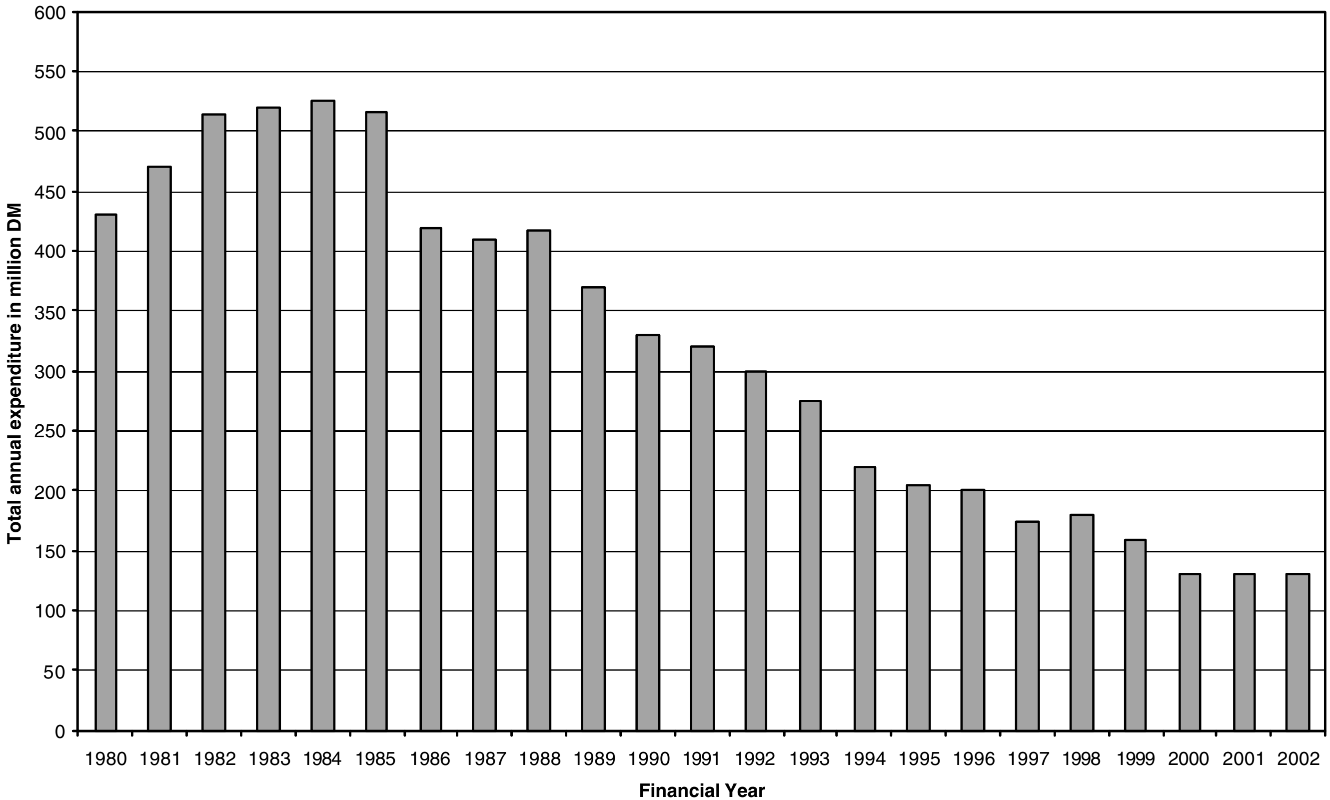

FIG. 3. Government funding of nuclear research.

years. Operations will be stopped when the allocated electricity volume has been reached. The Agreement does, however, allow electricity production quotas to be transferred between nuclear power plants, but in principle only from less modern to more modern plants, and from smaller to larger plants (Fig. 4).
- The safety of nuclear power plants will continue to be based on the current state of science and technology.
- Periodic safety reviews every ten years will be legally prescribed for nuclear power plants.
- For the case of nuclear accidents, the level of insurance cover will be raised to €2500 million, which is almost a tenfold increase.
- The energy utilities will make no claims for compensation.

3. ACTIVITIES OF THE NUCLEAR REGULATORY BODY IN GERMANY

The following experiences and activities of the German nuclear regulatory authorities that are to be applied to counteract the current challenges to nuclear safety in selected areas are discussed in Sections 3.1–3.5:

- Regulatory approaches to power operators' organizational changes and staff development;
- Establishment of a safety culture, safety management systems and performance indicators;
- Modernization of the safety related regulations to the current state of the art in science and technology;
- Maintenance of strong nuclear regulatory supervision and effective periodic safety reviews;
- Measures to preserve competence and infrastructure for the plants' residual operating lives and for overcoming the consequences of the use of nuclear power.

3.1. Regulatory approaches to power operators' organizational changes and staff development

The electricity market in Germany was deregulated in 1998. Shortly afterwards the nuclear authorities in Germany had to react to the mergers of large German utility companies and to attempts to carry out drastic cuts in the number of staff at nuclear power plants. Among the licensing prerequisites, according to the German Atomic Energy Act, are sufficient trustworthiness and technical qualifications on the part of

NPP	Date of commercial operation	Operating time in years so far	Electrical energy generated since first synchronization until 31-12-1999 (in TW·h)	Residual electricity volume * [TW·h]	"Calculated" residual operating life
Obrigheim	03/69	31	76.0	6.70	2002
Stade	05/72	28	134.0	23.18	2004
Biblis A	02/75	25	179.5	62.00	2006
Neckarwestheim-1	12/76	24	137.5	57.35	2008
Biblis B	01/77	23	177.5	61.46	2008
Brunsbüttel	02/77	23	87.6	47.67	2008
Isar-1	03/79	21	127.2	78.95	2009
Unterweser	09/79	21	193.3	117.98	2010
Philippsburg-1	03/80	20	119.3	87.14	2011
Grafenrheinfeld	06/82	18	174.4	150.03	2013
Krümmel	03/84	16	137.6	158.22	2015
Gundremmingen B	07/84	16	142.9	160.92	2016
Gundremmingen C	01/85	15	134.1	168.35	2016
Grohnde	02/85	15	168.4	200.90	2016
Philippsburg-2	04/85	15	159.7	198.61	2016
Brokdorf	12/86	13	137.3	217.88	2016
Isar-2	04/88	12	127.7	231.21	2020
Emsland	06/88	12	128.3	230.07	2020
Neckarwestheim-2	04/89	11	118.5	236.04	2021
Mülheim-Kärlich	10/87	2**	11.3	107.25	
			2,670.3 TW·h total produced so far	2,623.30 TW·h agreed residual electricity volume	

** of which 13 months of electrical supply; out of operation for legal reasons since 1988

* as from 1-1-2000, transferable to other NPPs

(1TW·h corresponds to 1 bn kW·h)

Sources: atw, RWE, VDEW

FIG. 4. Results of the Consensus Agreement.

the licensees.[1] The transfer of full responsibility for the safe operation of a facility to a licensee is effected by the naming in the operating licences of the responsible persons or their representatives. Further binding regulations for persons and organizational structures are specified in the organization of plant personnel, the control room and shift organization, the maintenance regime and in other organizational regimes. However, what is not specified in detail in the German regulations or licensing decisions are the requirements for staff numbers and for the allocation of areas of responsibility to certain numbers and competencies of qualified personnel, nor fundamental requirements for changes intended by a licensee.

The mergers of utilities in Germany went hand in hand with changes in the regulated responsibilities, directive powers and organizational forms. Such changes require a licence. The aim of such mergers is to realize potential savings and, for example, to consolidate specialist competencies at the utility headquarters. Here, however, it has to be ensured that each plant director, who by law is responsible for safe operation, continues to have direct access to the key specialist competencies that are required on the site for the comprehensive fulfilment of his or her safety responsibility. All the possible consequences of organizational changes in connection with mergers are checked before licences are issued. The following two aspects are of central importance:

— Are the organizational prerequisites with regard to clear responsibility structures still given and are the responsibilities, technical qualifications and competencies of the persons in charge suitable?
— Do the competencies (i.e. the key competencies) that remain within the plant, which are necessary to specify the services used, monitor their execution in a qualified manner and assess the results of those external services rendered?

As regards cuts in the number of staff, it can be stated that the relevant German guidelines only specify that personnel have to have the requisite technical qualifications, but not how many staff there have to be and which of them have to be technically qualified in particular disciplines. In this respect it was, in principle, quite possible for utilities to cut down staff numbers gradually. In one particular case, the

[1] According to §7 of the Atomic Energy Act, a licence may only be granted if (1) there are no known facts giving rise to doubts as to the reliability of...the persons...responsible for the...management of the installation and the supervision of its operation have the requisite qualification; and (2) it is assured that the persons who are otherwise engaged in the operation of the installation have the necessary knowledge concerning the safe operation of the installation, the possible hazards and the protective measures to be taken.

management of a utility wanted to duplicate its experience with drastic staff cuts carried out at its conventional power stations at its nuclear power plants. From the nuclear regulatory point of view, any intended changes in an organization or planned cuts in staff figures in a technical area need to be notified to the supervisory authority. The latter then decides whether it approves or whether there is a need for a formal licensing procedure. In addition, reports on actual staff numbers in technical areas and on positions that have become vacant and that have not been refilled immediately have to be submitted at regular intervals.

On behalf of the BMU, experts are currently formulating technically supported criteria to specify the minimum number of staff and the requisite technical qualifications of personnel at power plant sites necessary for their safe operation. These criteria should be applicable irrespective of the specific conditions of the different operators, for example with regard to their own and outside personnel or to the possibility of consulting competent external institutions and experts. So far it is too early to assess the effects of mergers or moderate staff reductions on the assurance of safety. More regulatory efforts will be needed in the future. The requirements for the justification of organizational and personnel changes, as well as the procedures and assessment criteria for examination by authorities, have to be further developed. Here, experience from previous cases can be used on an initial basis. In addition to that, indicators are needed that permit an early recognition of losses of safety and the corresponding reactions to them. The basis for both requirements and indicators is a comprehensive conceptual framework developed under the concepts of ‘safety management’ and ‘safety culture’.

3.2. Development of safety management systems and performance indicators

Beyond the stipulations of the licensing decisions already mentioned above, there are no other formal requirements for licensees in Germany to define a specific safety policy or to introduce safety goals or a specific safety management system. It has to be noted, though, that the licensees, expert organizations and advisory committees of the BMU have developed, under the concept of ‘safety culture’, certain ideas and recommendations for an optimization of the management of safety [6, 7]. For this purpose, up to date international documents have also been consulted [8]. Considerations are going on as to how such approaches can be implemented with respect to both operational practice as well as to licensing and supervisory procedures. Also relevant are parameters and measuring instruments with which the efficiency of the safety management system, the so-called ‘safety performance’, can be monitored. Regulatory authorities need an early warning system with which the first indications of dilutions of safety can be recognized.

The German utilities already operate information systems for self-assessment or for the assurance of reliable and safe operational management. These information systems can also be used to derive indicators. For example, utility systems currently register and assess safety relevant operator actions, in particular human errors. The scope and degree of detail of these systems go beyond what has to be reported to the supervisory authorities. Provided such a system is considered as suitable by the supervisory authorities, an annual summary report by the utility to the supervisory authority could be useful, for example, in monitoring the relevant trends in the area of human errors. Other systems used or planned by the utilities should also be assessed with regard to whether they allow sufficiently up to date and comprehensive monitoring of safety performance and whether they offer means of early counter-action to problems.

Germany is participating in international consultations and projects relating to safety performance indicators. Such indicators are currently being tested for the evaluation and assessment of special events and are also used on a trial basis for the observation of safety relevant trends.

3.3. Modernization of the safety related regulations to the current state of the art in science and technology

During the nuclear phase out the high level of safety legally required with reference to the state of the art in science and technology has to be applied to plant operations, licensing and supervision. In the Consensus Agreement, the Federal Government stated that it will take no initiative to change either this standard or its underlying safety philosophy. If the legal nuclear requirements are fulfilled, the Federal Government has guaranteed that plant operations will be undisturbed.

The legal requirements concerning safety standards and safety philosophy are phrased in rather general terms and require specification by subordinate legal and sublegal regulations. Decades of controversy with regard to nuclear power in Germany have contributed to the fact that the development of legally binding nuclear regulations was politically controversial and stagnated. Regulations are still incomplete and antiquated. However, there has been a dynamic development of safety practices by the nuclear industry at the supervisory authorities' urging. This development is partly based on the requirements stated in the licensing decisions and partly on voluntary commitments by the licensees, as, for example, in the case of retrofits, periodic safety reviews or in connection with the introduction of accident management measures.

In the sublegal area there exists in Germany a great deal of detailed technical regulations. The Safety Standards of the Nuclear Safety Standards Committee (the KTA) are worked out and approved jointly and in a consensus oriented manner by all the parties involved, namely the manufacturers and licensees, authorized experts, safety authorities and public representatives. These standards are reviewed every five years for necessary updates. This instrument will be used for the due modernization of the nuclear regulations.

The draft rule in which the fundamentals of this procedure are to be laid down was put forward for review and comment in July 2001 [9]. There are seven other basic KTA rules subordinate to this fundamental draft that describe in more detail the substantial protection goals, fundamental requirements and procedures that assure these protection goals in line with the state of the art in science and technology. The basic rules concern the four protection goals of reactivity control, fuel cooling, the confinement of radioactive substances and the limitation of radiation exposure; they also cover the general technical requirements, verification methods, and personnel and organizational measures.

This new KTA approach also helps to simplify the integration of international rules and specifications into the German national regulations so that changes, in particular in manufacturing and the supply markets, can be taken into account. The safety authorities will more and more be confronted by the fact that foreign produced plant equipment that does not fully meet the requirements applied so far is to be used. The utilities will more and more be looking for solutions in the international markets. In those areas where, despite the plant specific and operational differences between the nuclear power plants in Europe and elsewhere, such an international market does exist, challenges will arise for the nuclear authorities to develop consistent requirements concerning safety requirements, as well as demonstration methods and test procedures, and to verify that these requirements are fulfilled.

From the German point of view, the major emphasis in this context has to be that the dynamic development of the state of the art in science and technology, as required by the German Atomic Energy Act, continues to be realized.

3.4. Maintenance of strong nuclear regulatory supervision and effective periodic safety reviews

Practical supervision by the nuclear authorities in Germany takes place very close to the plant under supervision; numerous external, independent experts are consulted, who visit the plants regularly. For each plant the annual average of supervisory authority personnel needed is three authority staff and 30 authorized experts. The annual costs amount to up to DM 10 million (about US $5 million). The nuclear authorities consider that this expenditure is necessary and see it as a prerequisite for the preservation of competence and first hand experience for nuclear safety experts.

Our experience has been that very often the real safety significance of any defects, such as in materials or valves, only comes to light after a very detailed examination. Working through the whole process requires not only key competencies on the part of the utility, but specialist knowledge of the industrial enterprises and experts consulted. It also requires a high level of competence on the part of the authorized independent experts needed to perform assessments on behalf of the supervisory authority. It is necessary that nuclear authorities rely on independent experts with extensive technical knowledge of even the smallest details. German regulators consider this practice a strong line of defence against the safety challenges from external factors.

Another instrument to maintain key competencies and well founded safety practices are periodic safety reviews (PSRs). PSRs have so far been carried out in Germany to fulfil the requirements imposed in licence notifications or as a result of voluntary commitments on the part of the utilities. This practice is now to be regulated as a binding obligation within the framework of the amendment of the Atomic Energy Act. A schedule for the next set of PSRs has been agreed with the utilities as part of the consensus on the nuclear phase out. Based on experience with past PSRs, the requirements for their execution and assessment are to be developed further, in co-operation with those involved. The German safety authorities consider the practice of performing PSRs to be an essential contribution to the preservation of specialist knowledge of design and operations among future utility staff, as well as to the practical provision and utilization of new scientific and technical methods and findings. Periodic safety reviews in Germany comprise a safety status analysis, an analysis of operating experience and proven operational performance, a probabilistic safety analysis, as well as a physical protection analysis. The review must be based on the current plant status and the operating experiences available until then, and has to contain an estimate on the assurance of safety for the operating period to follow. As for the systematic registration and provision of the necessary information, there must be a close link to the plant’s safety management. It is therefore necessary to discuss with the licensees how the data and information needed to execute future PSRs can be compiled and made available as efficiently as possible.

3.5. Preservation of competence and infrastructure for the plants’ residual operating life and for overcoming the consequences

The German regulatory body has analysed the future development of its staff and has initiated a programme to maintain competence. The problems to be solved, however, have to be seen in a much broader context. In 1999, the Federal Minister of Economics and Technology (BMWi) set up an evaluation commission to review the state funding of nuclear safety and repository research in Germany [3]. A comprehensive survey was carried out of professional competence among licensees, plant vendors, the service industry, supervisory and expert committees, and research and development institutions. According to the results of this survey, drastic measures are needed to ensure the necessary professional competence during the plants’ residual operating lives and for the tasks to be developed over the next three to four decades for the decommissioning and disposal of the nuclear facilities.

As a first step, the Nuclear Engineering Competence Association was created in March 2000 to cover the field of nuclear safety research and technology. However, this collects together only the existing competencies and does not achieve a stabilization of the necessary future human resources with respect to university institutes and students, expert organizations and industry. Further steps are necessary in these areas.

The consensus on the nuclear phase out provides all those responsible with a clear framework for planning their respective tasks and estimating the necessary human resources and professional competencies needed. On this basis it is possible to develop concrete steps in order to tap the necessary resources, both nationally and within the framework of a large international association.

4. CONCLUSIONS

Phasing out nuclear power on the basis of limits for power production, as decided upon in Germany, is an adequate policy to cope with the nuclear safety challenges from external factors. Even if the residual operating lives of nuclear power plants are limited, as is the case now in Germany, the assurance of a sufficient nuclear infrastructure for nuclear safety, decommissioning and waste management, that is a sufficient number of qualified experts, effective organizations and competent industries, requires major national and international efforts, especially by the nuclear industry.

The implementation of efficient safety management systems and related safety performance indicators, together with a strong, highly qualified regulatory body that has access to up to date, independent nuclear safety expertise, are the two strategic necessities for maintaining and improving nuclear and radioactive waste safety under the increased pressure of external factors. A further strengthening of international co-operation for advances in nuclear safety methods and technologies and for a harmonization of nuclear safety regulations and procedures is necessary to maintain and improve nuclear safety under increased economic competition.

REFERENCES

[1] Convention on Nuclear Safety, First Review Meeting of the Contracting Parties, 12–23 April 1999, Vienna, Summary Report.

[2] FRITZ, P., et al., Vorauseilender Ausstieg aus der Kernenergie an den deutschen Hochschulen und Forschungszentren?, Arbeitsplätze und Studienangebote im kerntechnischen Bereich, atw 46.Jg (2001) Heft 2 – Februar.

[3] Kompetenzerhaltung in der kerntechnischen Industrie, Dr. Ralf Güldner, Framatome ANP GmbH, Jahrestagung Kerntechnik, Fachsitzung Betrieb, Dresden (2001).
[4] Agreement between the Federal Government of Germany and the utility companies, 14 June 2000.
[5] Entwurf eines Gesetzes zur geordneten Beendigung der Kernenergienutzung zur gewerblichen Erzeugung von Elektrizität, 5 July 2001.
[6] RSK-Memorandum: Sicherheitskultur, under discussion.
[7] Sicherheitskultur in deutschen Kernkraftwerken, Engagement der Führung, Engagement des Einzelnen, Sicherheitskultur, Unternehmenskultur, VGB (September 1999).
[8] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Management of Operational Safety in Nuclear Power Plants, INSAG-13, IAEA, Vienna (1999).
[9] KTA-Sicherheitsgrundlagen, Fassung 6/01 (2001).

Keynote Paper

SAFETY IN A CHANGING ENVIRONMENT: CAN WE DRAW LESSONS FROM OTHER INDUSTRIAL SECTORS?

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Abstract

SAFETY IN A CHANGING ENVIRONMENT: CAN WE DRAW LESSONS FROM OTHER INDUSTRIAL SECTORS?

Many industries confront vital economic and political changes at key times of their development, which may have an impact on their level of safety. As an example, the safety records of the air transport industry in the USA and the rail transport sector in the UK are contrasted through the two major changes these sectors underwent in recent history: deregulation under President Carter in the late 1970s and privatization of British Rail under Mrs. Thatcher. While deregulation did not seem to adversely affect the safety of air travel in the USA, safety in the rail sector in the UK has apparently dropped markedly. Using parallels involving mergers or splitting up scenarios from industrial sectors, some lessons are drawn for all safety critical industrial systems, in particular for the nuclear industry, and the concept of cyndinics, a methodical and scientific approach to danger and risk, is introduced.

1. INTRODUCTION

Facing a changing political and economic environment is not a situation unique to the production of electricity. Nearly all industries have been facing similar situations for many decades. Safety is a vital requirement for industrial development. Yet this is true not only in the area of electricity generation through nuclear power, but also for many other industries, which have to comply with safety obligations for legal and ethical reasons.

Many industries have had to face a changing political and economic environment while maintaining a high level of safety, and some have fostered safety to standards that are higher than ever. Air transportation, the chemical industry, the siting of buildings, mining and rail transportation have addressed this challenge, or are still confronting it. Can we draw some lessons from the experience of other industries?

2. DEREGULATION OF AIR TRANSPORTATION IN THE USA

Air transportation had to face deregulation and its consequences. Originally, the possibility of carrying fare paying passengers was subject to a form of governmental authorization. For international air transportation it could even be said that the regime was a double governmental authorization: this stemmed from both the country where paying passengers embarked and their country of destination. In addition, in many countries the largest airline was, in one way or another, either partially or totally owned by the government.

In the 1960s, President Carter decided to deregulate air transportation in the USA. The federal body in charge of granting authorizations (the Civil Aeronautics Board) was disbanded. Following this example, many other countries deregulated to some degree their internal air transportation networks. Some countries privatized their government owned airlines totally or in part. On the international scene, "open skies" agreements developed.

The consequences of such deregulation are well known. In a first stage, new entrants appeared, the number of services multiplied, in particular point to point (no stopover) services, and fares decreased under the pressure of competition.

In a second phase, the less competitive airlines collapsed, their real market assets (in particular airport slots) becoming concentrated around a limited number of 'big ones'. These larger companies reorganized their routes into a 'spoke and hub' system, with a large decrease in the number of direct flights to and from smaller communities. Staff costs were severely cut (along with significant salary decreases). Tariffs started to flatten and, on some routes, even increase.

During the whole process, many claimed that deregulation and liberalization would jeopardize safety, either globally or as a result of a specific merger or cost cutting plan. However, neither the statistics of the International Civil Aviation Organization (the UN aviation counterpart to the IAEA), nor those of the US Federal Aviation Administration show an increase in the air transportation risk, which can best be measured by the fatal accident rate by million hours flown. This does not negate the fact that, for certain accidents, the response of one partner in the air transportation system to a severe competitive environment may have been found to be a cause of a crash scenario.

3. PRIVATIZATION OF RAIL TRANSPORTATION IN THE UK

In the UK, rail transportation was subjected to a more severe change in environment when Mrs. Thatcher decided to privatize British Rail, the government held company. It is interesting to compare the kind of organization retained by the British Government for rail transportation with the one in use for air transportation:

— In both cases the *'tracks'* remained a monopoly: Railtrack, a company owning all tracks in the UK and operating them (tracks and signals, maintenance and operation) and National Air Traffic Systems (NATS), mostly a government owned entity[1] maintaining ground equipment for air navigation and operating 'airways'.
— For both air and rail transport, *stations/airports* remained a monopoly even when some degree of competition might have been feasible, at least in theory. As an example the three airports serving the City of New York (John F. Kennedy, La Guardia and Newark) are run by the Port Authority of New York and New Jersey, with no real competition. Similarly, Heathrow and Gatwick are under a similar type of body, the British Airports Authority. So also are the airports of Charles de Gaulle and Orly in France.
— For both aviation and the railways in the UK, the *vehicles* using the 'tracks' are in the real competitive world: the modalities of ownership, organization and, in particular, the degree of subcontracting, including maintenance and training (by simulation), may vary widely.
— When it comes to *safety*, however, the contrast is striking: the safety record of rail transportation in the UK is far from acceptable (the author does not have statistics on railway accidents in the UK that are as reliable as those on civil aviation).

4. BASIC DIFFERENCES IN THE DEVELOPMENT OF THE RAIL AND AIR TRANSPORT ORGANIZATIONS

Why have two transportation systems, which seek to build organizations that rest upon many comparable features, achieved *totally opposite safety results?* Since its creation, air transportation has never been amalgamated into unified companies owning and running all components of the system, as had been British Rail (and many other railways in Europe). Airways, airports, airlines had always been different entities, even when under public ownership. Subcontracts for aircraft maintenance and for ground handling had been common practice. Consistent with this diversity of partners, governments developed strong, competent and credible authorities for civil aviation safety. Regulations were technically up to date, and an enforcement procedure was used when appropriate; lessons were drawn from all accidents.

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[1] However, the old 'NATS'in the UK is now being privatized.

When deregulation was initiated in the USA, even though the federal body in charge of economic regulation was disbanded, as mentioned, the federal authority in charge of safety regulations and their enforcement was reinforced and a reporting system to the Congress was set up to provide political feedback on safety. Prior to deregulation, airlines were using reasonably modern technology and invested adequately in safety equipment and in training of staff. For civil aviation, deregulation lead to new entrants into the industry and to mergers, rather than to the splitting up of "large players" into smaller entities. Can we also assume that while a 'safety culture' comparable to the concepts put forward in a report by the International Nuclear Safety Advisory Group[2] had been widespread in aviation, it was less visible in rail transportation?

5. RELEVANCE FOR ALL SAFETY CRITICAL INDUSTRIAL SYSTEMS

From this rather simple comparison it seems that conclusions can readily be drawn for all safety critical industrial systems, in particular for the nuclear industry. Subject to further debate, the following conclusions seem applicable:

— An industrial system based on a diversity of partners, with different kinds of ownership (private, community, government), all linked by contracts and regulations, is not per se detrimental to safety.
— Similarly, mergers of companies do not appear per se to be detrimental to safety.
— A critical situation for safety is the transition phase from one organization of the system to another. It has to be prepared, organized and carefully monitored.

Before cutting a previously 'solid' system into 'independent' parts, one has to make sure these cuts are made at places where partners know how to specify in detail their relationship. Quality systems, ISO standards and industrial specifications (e.g. ASME) are useful in this context, but are not complete enough to cover all situations. They must be complemented by an important programme that will set out in writing all the organizational and operational aspects which ordinarily need not be explained in a 'solid' organization, to the mutual satisfaction of both sides of the divided entity. Safety regulatory authorities have an important role to play in ensuring that this

[2] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Safety Culture, Safety Series No. 75-INSAG-4, IAEA, Vienna (1991).

interfacing programme is efficient. It should be noted that this programme should not be run only by ‘contract departments’ of the future independent entities, but also by those who day after day ‘knit’ safety in the production process.

- — In this interfacing programme, special care should be given to all human aspects which complement procedures by providing consistency throughout the process: from the coffee machine and site restaurant through to university fellowships, diffuse human links are paramount in a transition. Top corporate management should be visibly promoting safety, as requested in Safety Series No. 75-INSAG-4; Management messages promoting competitiveness should not appear as a ‘new management’ replacing the previous one with all its contents, including safety. INSAG-13, on safety management[3], should be the authoritative sourcebook for all management, in particular at the upper corporate echelon. A frequent deviation from this principle is when the existing hierarchical lines, whose function is to integrate all management messages, are repeatedly short circuited by other ‘message diffusers’ such as the communications department.
- — Corporate management should make very clear that, even in a highly competitive environment, open communication between competitors on certain subjects, notably safety, is a prerequisite for their development. Competition between Airbus and Boeing does not prevent them from being active partners in a large programme to improve the safety of aviation in the future (FAST programme).

6. OTHER INDUSTRIES THAT UNDERWENT COMPARABLE TRANSFORMATIONS

Other industries that went through a similar transformation could be considered, and data could be collected on their history, environment and safety.

6.1. The chemical industry

The chemical industry has been subject to major mergers, purchases and closures of units under nearly all of the situations listed in paragraph 1 (Rationale) of

[3] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Management of Operational Safety in Nuclear Power Plants, INSAG-13, IAEA, Vienna (1999).

Topical Issue Paper No. 2, Impact of External Factors on Safety. Apparently, except for the Bhopal accident (the ‘Chernobyl-type’ accident of the chemical industry), safety has not been dramatically undermined by the numerous changes.

6.2. The pharmaceutical industry

Pharmaceutical producers have also been subject to major rearrangements which do not seem to have impacted on the high quality standards of drugs and medications.

6.3. The mining industry

The mining industry has also faced increased competition, which has led to the closure of many mines in developed countries. The effects on safety there are more open to question in the absence of relevant data.

6.4. House siting

House siting has moved from the century old practice of where to build houses safely to urban mass concentrations. Today, safety issues with regard to the possibility of floods and earthquakes do not appear to be properly taken into account.

6.5. Cindynics — the scientific approach to dangers and risks

Other domains may also have been or will be subjected to dramatic changes in their socioeconomic environment. A scientific approach to dangers and risks, based on cross-comparisons between different industries or social activities, has developed, in particular in France and Canada, under the name of ‘cindynics’ (from the Greek word ‘kindunos’, or danger). This approach addresses safety issues in a comprehensive, systemic and transverse manner (transverse to domains, to techniques, to sciences, etc.).

7. RECOMMENDATIONS TO THE CONFERENCE

The questions put to the conference in Topical Issue Paper No. 2 should be answered bearing in mind all the lessons that can be drawn from the experience of other sectors. It is therefore proposed that the meeting put forward the following recommendations:

— Those in charge of developing efficient safety management under the concepts set forth in 75-INSAG-4 and INSAG-13 should develop a 'cindynic' culture by cross-comparison with other industrial sectors subjected to a changing environment. INSAG-13 should specifically refer to it as cindynic culture.
— The IAEA should take the initiative to develop an 'Inter-United Nations Bodies Safety Forum' to exchange views on the responses of different safety critical industries to a changing environment. Bodies such as ICAO (for aviation), WHO (for health), IMO (for maritime affairs) and UNESCO should participate in this forum; other international organizations and research establishments may also be invited.

Lead-in Discussion

NUCLEAR SAFETY REGULATION IN A CHANGING ENVIRONMENT

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1. INTRODUCTION

The process of privatization and the opening up of the energy market will enhance competition in the energy industry and bring about a far-reaching restructuring in this sector. As a result, major changes in how nuclear power plants are operated may occur, and additional challenges may arise for nuclear safety. Handling these important issues should be subject to international co-operation in the future, inter alia by the IAEA, OECD Nuclear Energy Agency and the relevant bodies of the European Union.

2. DISCUSSION

The Czech Republic is, like other countries, considering the possibility of deregulating the electricity market. Nevertheless, in a deregulated market, the main task of the Czech nuclear safety regulatory authority will remain the same: to ensure that licensees fulfil their safety obligations under the law. What will be different will be how these tasks will be discharged effectively, and how it will be determined that the legal requirements continue to be adequate.

The Czech Atomic Act allows both a prescriptive regulatory approach through the issue of regulations and, to some extent, a non-prescriptive approach through the establishment of license conditions and licensee arrangements. A balance should be struck between both approaches because developing regulations, codes and standards is very resource intensive for a regulator. Licensees, for their part, have considerable expertise which is valuable in developing innovative solutions in the area of safety enhancement. A non-prescriptive approach has the benefit of being flexible and can respond to changing situations quickly. It also fosters a sense of primary responsibility of the licensee in ensuring safety. Notwithstanding this, there are principal provisions in the Atomic Act which give the State Office for Nuclear Safety (Office) the authority to overrule the licensee in controversial cases.

The CEZ Company, the only holder of a licence in the Czech Republic to construct and operate the Dukovany and Temelin nuclear power plants, is subject to regulatory oversight and assessment on an ongoing basis. The Office monitors significant safety and regulatory issues at the four units of the Dukovany nuclear power plant that are licensed to operate and at the two units of the Temelin nuclear power plant that are currently in the commissioning stage. Although a number of findings have resulted from safety assessment and inspection activities, the Office is in general satisfied with the licensee's reaction to the items identified. Both Dukovany and Temelin are constantly enhancing their performance and devoting the necessary financial and human resources to enhance the level of safety of their installations.

In accordance with the Atomic Act, inspections are one of the main tools for the verification and assessment of nuclear safety. The Office conducts inspections of reactor facilities based upon plant changes, current plant work, events and the in-service inspection programme of the licensee and deterministic information provided by it. Risk information from the risk oriented assessment at the Dukovany nuclear power plant was used during a review of instrumentation and control (I&C) modifications. Temelin is in the phase of commissioning and limited power operation; the inspection programme reflects this condition. Inspection activities of the Office do not cover all aspects of the activities of licensees; a sampling approach was adopted and the Office plans its work mainly around safety priorities. The Office uses its professional judgement, feedback from site inspectors and previous experience to determine areas for investigation.

Good international practice requires that a frank, open and yet formal relationship based on mutual understanding and respect be established between the regulatory body and the utility. Both the Office and the utilities have dedicated special efforts to foster the establishment of such a relationship in past years. Meetings are held on a regular basis at different levels between the utilities and the Office. This dialogue has enabled a process to be established to address safety policy issues as well as important issues related to the actual regulatory process.

The Office has all the necessary prerequisites to accomplish its duties, but more importantly, it has all the necessary tools, including legal instruments, to effectively withstand direct or indirect pressures coming from different political, economic or other interest groups. This is of special importance in today's world, where political decisions are quite often taken in the name of safety, but are not based on sound safety analysis. This is clearly exemplified by the startup of the Temelin nuclear power plant. The design of this plant, which is based on the project of a nuclear power plant with WWER-1000 reactors, has been modernized extensively. Each and every step of the startup is naturally preceded by intensive reviews and inspections carried out by the regulatory authority. In line with international practice and with the national legislation in force, the Czech Government fully respects the assessment of nuclear safety as carried out by the independent regulatory authority.

Despite this fact, the startup of the first unit of Temelin has been the subject of many discussions. Since 1982, Czech and Austrian experts have exchanged information on the Temelín nuclear power plant at regular meetings under the framework of a bilateral, intergovernmental agreement. Co-operation with Germany, as an operator of nuclear power, is even more extensive. In the exchange of information, the Office has always stressed the importance of documents resulting from international review processes and missions to the regulatory authority and the plant itself. Any judgement as to the level of nuclear safety achieved at the Temelin nuclear power plant should be based on the Czech National Report under the Convention on Nuclear Safety, which is up to now the only internationally binding document in this field. Many safety reports from IAEA missions in connection with Temelin are also available. Finally, a report on nuclear safety in the Context of EU Enlargement was prepared by the AQG/WPNS under COREPER in June 2001. The report evaluates legislation in the nuclear sector, the organization and management of regulatory authorities and the level of safety of the installations in each of the Candidate States with a view to defining the European Union's position on a "high level of nuclear safety" to be requested in those countries. And, last but not least, there is an update to the 2000 report of the Western European Nuclear Regulators' Association. To date, these documents have been almost totally ignored at both the political and non-governmental organization levels in Austria and Germany, even though these circles otherwise demonstrate a keen (and legitimate) interest in the nuclear safety of installations on Czech territory. There have even been attempts to undermine the competency of the regulatory authority. I would hope that all the parties concerned will finally avail themselves of the results of these peer reviews, which are always made available to the public.

Turning to the issue of the discussion on nuclear safety matters in the context of the enlargement of the European Union, I must say that we are unfortunately still experiencing overlapping and multiplication of efforts. If no action is taken to avoid duplication, the future role and credibility of international organizations such as the IAEA in making safety recommendations could be progressively called into question. Therefore, I would like to call for more co-ordination of these activities at the international level, with a higher involvement on the part of the IAEA. We would like the IAEA to consider speaking up more for the results of reviews carried out under its umbrella. An initiative is also needed to let the public and politicians know more on nuclear safety requirements and recommendations and on the measures taken at given periods of the life of nuclear power plants, from design all the way to decommissioning. This is essential to allow us to concentrate on our basic duty — maintenance of the level of safety of nuclear installations and protection of the public.

Lead-in Discussion

NUCLEAR SAFETY IN A DEREGULATING ENVIRONMENT

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1. INTRODUCTION

Nuclear safety abhors chaos. As many nations find themselves in various stages of deregulating their energy systems, a potential for economic, and thus political, chaos exists should such deregulatory plans fail.

There are two reasons why nations, or in some cases individual States, choose to deregulate their energy systems. As a general rule, in developed nations the goal is to lower the cost to consumers through competition. On the other hand, developing nations generally follow the deregulatory path as a means of selling off State assets for cash and to entice the foreign capital required for the creation of new power facilities.

As developing nations seek to meet their goals of meeting current electricity needs and substantial electricity growth demand rates of 5–7% or higher in some instances, privatization is quickly becoming the only option available as such nations lack the capability of financing such projects through internal sources. Thus, as both developed and developing nations find themselves in various stages of deregulation, it is important to understand the risks associated with such plans and then gauge the threat to nuclear security accordingly. There is no better example for analysis than California's highly publicized failures. Let us take a moment or two to conduct a review of the situation in California.

2. DISCUSSION

In the early 1990s, California found its economy to be in a significant recession, caused in part by the economic slowdown throughout Asia. Segments of California's manufacturing sector were relocating to adjacent states, or even farther away as a means of reducing costs because, as everyone already knew, it is expensive to do business in California. Among other reasons, our electricity costs were high. Thus, as a financing enhancement to remain in the state, an attempt was made to reduce these high electricity costs by permitting direct access between suppliers and large consumers.

The deregulation law passed and became law in September 1996, and the market began operating on 1 April 1998; coincidentally, April 1 in the USA is always celebrated as April Fool's Day, when we are all supposed to play practical jokes upon one another. How appropriate. We learned very quickly that the rules to implement the market were wrong. The utilities had been ordered to immediately divest one-half of their generation, which they were pleased to do, but this left them vulnerable to the new, independent producers. By the rules, the utilities were severely restricted in their ability to enter into long term contracts, thus forcing purchases through the much more volatile spot market. Spot market prices were set at the last price bid, thus guaranteeing maximum spot prices. Then, importantly, a temporary retail rate cap was imposed at 10% below 1996 prices. This was done in recognition that the law was designed to benefit the big electricity users and not the household or small business consumer. Thus, incentives were put in place to encourage legislators to support the law, which they did unanimously.

At the same time that the market was just getting started, the state entered into a period of supply shortages. Although reserves had been adequate through 1995–1996, the heated California economy pushed electricity growth from 2 to 2.5%, and in some areas of the state, such as in Silicon Valley, up to 3%. No new power was added to the system from 1994, due to the anticipated transition to the free market. During this period also, California's reliance upon imports for 25% of its power was threatened as neighbouring states were experiencing their own significant population increase, which captured all available reserves. Thus, by 1999, California's reserves were reduced to less than 10% and on certain days to less than zero.

Thus, conditions were presented which combined defective rules and true market shortages to create opportunities for the independent power producers to exercise market power which they did, resulting in spiked wholesale prices far exceeding the capped retail rates. The result was utilities at or near bankruptcy and the state was $20 thousand million in debt from power purchases.

None of this, however, need have occurred. Within a few months of the opening of the market, professional monitors were warning of market dysfunction. These warnings continued all through 1999, and into the spring of 2000. Thus, when the retail rate caps were lifted in May 2000, and prices tripled and quadrupled, few experts were surprised. The failure to respond to the warnings was the result of gross negligence by the state's leadership and responsible appointees. Had reasonable remedial steps been taken at any time in 1999 or through June 2000, there would not have been a crisis and rate increases would have been negligible. In summary, the failure was not economic, it was human. This being the case, our failures need not be repeated elsewhere.

Nevertheless, questions were properly posed as to whether our days of rolling blackouts and high costs posed a threat to the safety of our two operating nuclear plants. The answer was, clearly, no! This is in spite of the fact that the owners/operators of the two plants, Pacific Gas and Electric and Southern California Edison, have been at or near bankruptcy.

The Nuclear Regulatory Commission (NRC), as the Federal agency responsible for plant safety, has closely monitored the California market. As California's Liaison to the NRC, I have personally met with Richard Meserve, the Chairman of the Commission, to discuss the need for modified procedures. I am personally acquainted with the leadership of the NRC's Region IV, which is responsible for California, and I have a high degree of confidence in their capabilities to respond to any changing circumstances as may be required. No such changes are anticipated. Even the bankruptcy, or the threat of such by the operators, will not impact safety. Federal bankruptcy courts have extraordinary powers and would have unlimited authority to reinforce safety measures as may be necessary. The court, in Pacific Gas and Electric's case, is aware of the issue, but to this point, there has been no need to act.

This, however, is not the end of the story. As you may be aware, the NRC, in response to industry complaints of outdated and costly inspection procedures, has revised them, placing greater reliance upon the owner/operators for daily inspections. I have participated in the initial review of the new procedures and found them to be satisfactory. Nevertheless, certain segments of the public consider any lessening of on-site inspections or resident inspectors to pose a serious threat to plant safety. Additional cost cutting efforts by operators will continue to put pressure upon regulating agencies to co-operate as long as industry has the support of Congress on the issue.

The question of the impacts of deregulation is not as easy to answer outside of the USA. As noted, the combined utility and state debt in California as a result of power purchases exceeds $20 thousand million and many expect that figure to double. Even so, California's economy will not immediately collapse as most of the burden of repayment will fall upon big business, which is ironic since the whole rationale for California's decision to deregulate was based upon the financial needs of these very same business enterprises. Accordingly, the greater economic harm to the state will more likely be long term as California's manufacturing base packs its bags for less costly surroundings and takes the employment base with them. One can only speculate as to the economic costs. Nevertheless, these losses will occur over time and if new wisdom or courage is found, which heretofore has been lacking, the harm can be effectively managed.

Developing nations, with economies more fragile than that of California, may not have the luxury of time. As I have previously expressed, the California crisis need not have occurred and need not occur elsewhere. However, the fact is that chaos, both political and economic and the accompanying leadership panic, did occur and this could happen elsewhere.

In regions with fragile economies, where deregulation has or will be initiated for the reasons previously discussed, system failures occur even though, as I have said, if caution and wisdom are exercised, failure should not be routine or even probable. Nevertheless, any failure similar to California in a developing nation could prove to be catastrophic. Economies and political systems could fail in a very shortened time-frame. Serious chaos could then result and security could be threatened.

I thus believe it to be incumbent upon this agency or other tribunal to maintain a programme which monitors competitive markets. International assistance could foreseeably be required to maintain the safety of plants located in such insecure environments.

In conclusion, I repeat my belief that deregulation of electricity systems can and should work. It is especially important for developing nations that this be allowed to occur. However, failure could lead to chaos, and chaos could lead to threat. Vigilance is thus required.

Topical Issue No. 3

SAFETY OF FUEL CYCLE FACILITIES

(Session 3)

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Topical Issue Paper No. 3

SAFETY OF FUEL CYCLE FACILITIES

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1. RATIONALE

A wide range of nuclear fuel cycle facilities are in operation. These installations process, use, store and dispose of radioactive material and include: mining and milling, conversion, enrichment, fuel fabrication (including mixed oxide fuel), reactor, interim spent fuel storage, reprocessing, waste treatment and waste disposal facilities. For the purposes of this paper, reactors and waste disposal facilities are not considered. The term 'fuel cycle facilities' covers only the remainder of the installations listed above.

The IAEA Secretariat maintains a database of fuel cycle facilities in its Member States. Known as the Nuclear Fuel Cycle Information System (NFCIS) [1], it is available as an on-line service through the Internet [2]. More than 500 such facilities have been reported under this system. The facilities are listed in Table I [3] by type and operating status. Approximately one third of all the facilities are located in developing States. About half of all facilities are reported to be operating, of which approximately 40% are operating in developing States. In addition, some 60 facilities are either in the design stage or under construction.

Although the radioactive source term for most fuel cycle facilities is lower than the source term for reactors, which results in less severe consequences to the public from potential accidents at these fuel cycle installations, recent events at some of these facilities have given rise to public concern which has to be addressed adequately by national regulatory bodies and at the international level. Worldwide, operational experience feedback warrants improvements in the safety of these facilities.

Some of the hazards are similar for reactor and non-reactor facilities. However, the differences between these installations give rise to specific safety concerns at fuel cycle facilities. In particular, these concerns include: criticality, radiation protection of workers, chemical hazards, fire and explosion hazards. It is recognized that the relative hazards vary from facility to facility depending upon the processes employed. However, all installations should be designed and operated so as to keep all sources of radiation exposure under strict technical and administrative control. The design management should ensure that the structures, systems and components important to safety have the appropriate characteristics, specifications and material composition to perform the required safety functions. Emphasis should be placed on the use of proven engineered safety features in the implementation of the defence in depth concept in the facility design and operation.

In the past nine years, more than 30 events at fuel cycle facilities were reported under the International Nuclear Event Scale (INES) system. Since 1945, some 60 criticality accidents of varying degrees of severity have occurred, 22 of which were in nuclear fuel cycle facilities. The most notable recent event was the accident at the JCO facility in Tokaimura, Japan, in September 1999. As a result, some countries are currently revising their relevant regulations or standards to reflect the importance of the lessons learned.

TABLE I. NUMBER AND TYPE OF FUEL CYCLE FACILITIES

Facility type	Total	In developing States	Operating (number in developing States)	Planned (number in developing States)	Shut down or standby/ decommissioning	Decommissioned	Status unknown (not reported in database)
Milling (incl. PO_4)	189	77	58 (31)	20 (6)	53	55	3
Conversion	45	11	31 (7)	4 (0)	8	1	1
Enrichment	39	14	22 (6)	4 (3)	6	2	5
Fuel fabrication	72	19	49 (13)	4 (2)	10	9	0
Interim storage	99	16	67 (10)	26 (4)	4	2	0
Reprocessing	38	9	13 (3)	3 (2)	11	7	4
MOX fuel fabrication	22	1	10 (1)	3 (0)	4	1	4
Total	504	147	250 (71)	64 (17)	96	77	17

The development of nuclear safety standards is one of the tasks in the Statute of the IAEA. Over a number of years, the IAEA has developed a comprehensive set of publications which address, in a structured manner, the safety of nuclear installations. The Safety Fundamentals publication entitled The Safety of Nuclear Installations [4] presents an international consensus on the basic concepts underlying the principles for the regulation, design and operation of nuclear installations, including fuel cycle facilities. Detailed requirements and guides for activities relating to siting, design, construction, operation, decommissioning and regulation of nuclear installations are addressed by the lower hierarchy safety standards, which cover nuclear power plants (NPPs) and research reactors. Although some of the IAEA NPP standards can be adapted and applied to fuel cycle facilities, and some standards on criticality safety are published by the International Organization for Standardization (ISO), in general there is a lack of international standards to cover the safety of such facilities.

With a view to establishing a plan for the development of safety standards for fuel cycle facilities, the IAEA began to compile information on the status of national regulations and safety issues concerning such facilities. It also held a Technical Committee meeting on the topic in May 2000 [3, 5]. This paper draws on information compiled from these activities.

The main objective of this paper is to discuss the specific safety concerns for fuel cycle facilities and reach a consensus on actions to be taken by the national and international nuclear communities to ensure the safety of such facilities worldwide. It should be demonstrated that these facilities are operated and regulated in a similarly stringent fashion as NPPs to bolster public confidence.

2. STATUS OF THE TOPICAL ISSUE

Fuel cycle facilities differ from reactors in several important respects. They employ a great diversity of technologies and processes. Fissile material and wastes for these facilities are handled, processed, treated and stored throughout the entire installation. These processes use large quantities of hazardous chemicals, which can be toxic, corrosive or combustible. Consequently, the materials of interest to nuclear safety are more distributed throughout the nuclear installations, than in reactors, where the bulk of the nuclear material is located in the reactor core or in fuel storage areas. Moreover, the nuclear materials in fuel cycle facilities are often present in solutions that are transferred between tanks used in different sequences for different parts of the process. The facilities are often characterized by more frequent changes in operation, equipment and processes, necessitated by production campaigns, new product development, research and development, and continuous improvement. Fuel cycle facilities also rely to a great extent on operator intervention and administrative controls to ensure safety, instead of active or passive engineered controls. The energy usually released in accidental situations at such facilities is associated with criticality, decay heat or chemical reactions but its amount is relatively small, which explains why in general the consequences for the environment are rather limited. The hazard dependence on different facility and material conditions is illustrated in Table II [3].

2.1. SAFETY HAZARDS

2.1.1. Criticality

Criticality is integral to nuclear engineering safety for all installations, including nuclear power and research reactors. The prevention of criticality incidents includes, but is not limited to, any one or a combination of the following: control of the mass of fissile material present in the process; control of the geometry (limitation of the dimensions or shape) of processing equipment; control of the concentration of fissile material in solutions; and the presence of appropriate neutron absorbers [6].

For fuel cycle facilities, criticality prevention is a dominant safety issue. Radioactive material can be widely distributed throughout a fuel cycle facility. Fissile material may exist in different forms (fuel pellets, fuel elements, fuel rods, fuel assemblies etc.), and phases (e.g. different kinds of solutions, slurries, gases and powders). As a result, fissile material may easily accumulate in different parts of the equipment and may also escape from its primary containment through leakage and gather in unexpected places not designed to ensure criticality prevention. The distribution and transfer of potentially critical nuclear material requires operator attention to account for this material throughout the installation and thus ensure that nuclear criticality safety is maintained.

The hazards associated with criticality were reviewed at a conference in France in 1999 on 'The Risks of Criticality in the Nuclear Industry' [7], sponsored by the French nuclear safety advisory body (Institut de protection et de sûreté nucléaire). The conference reported that nearly 60 criticality accidents of varying degrees of severity had occurred since 1945. About one third occurred at nuclear fuel cycle facilities. Of these, 21 accidents killed 7 people and resulted in significant radiation exposure to another 40 individuals. Although most of the accidents occurred before the early 1980s, two occurred as recently as 1997 and 1999. Twenty of these accidents involved the processing of liquid solutions of fissile material, while none involved any failure of safety equipment or faulty calculations. The conference identified the main cause of criticality accidents as the failure to identify the range of possible accident scenarios, particularly those involving potential human error. This finding is especially significant for fuel cycle facilities, given their extensive reliance on operator and administrative controls to ensure safety.

TABLE II. SAFETY ASPECTS OF FUEL CYCLE FACILITIES

Facility type	Criticality	Radiation	Chemical toxicity	Fire/ explosion	Product/ residue	Waste storage	Ageing facilities	Decommis- sioning	Effluents	Maintenance
Mining/ milling		✳	✳	+	✳	✳	✳	✳	✳	
Conversion	+	✳	✳	✳	+	✳	✳	+		
Enrichment	+	✳	✳	✳	✳	✳	+	✳		
Fuel fabrication	✳	✳	✳	✳	✳	✳	+	✳	✳	+
Interim storage	✳	✳				✳	✳	+		
Reprocessing	✳	✳	✳	✳	✳	✳	✳	✳	✳	✳
MOX fuel fabrication	✳	✳		✳	✳	✳	✳	✳	✳	✳
Waste disposal	+	✳		✳			✳	+	✳	
Transportation	+	✳	+	✳				+		
Vitrification	+	✳		✳		✳		✳	✳	✳

+ : May be a concern depending on specific conditions (enrichments, composition, etc.).

✳ : A concern at most facilities.

A detailed review of the causes, progression and consequences of 60 criticality accidents which occurred in Japan, the Russian Federation, the UK and the USA is provided in the Los Alamos National Laboratory publication A Review of Criticality Accidents [8]. Two categories of events have been analysed, those that occurred in process facilities and those that occurred during critical experiments or operations in research reactors. It was noted that process facilities, carrying out operations with fissile material, are generally designed to avoid criticality accidents through physical and administrative controls. In these types of facilities, the operating personnel are usually not technical experts in criticality physics, but under normal working conditions they can be very close to potentially critical configurations. From the analysis of the criticality accidents it has been concluded that the 'human element' represents the dominant cause in all of the accidents. In many cases inadequate supervision, inattentive upper management and a lack of appropriate regulatory control contributed to the development of undesirable practices which eventually led to an initiating event causing the criticality accident. Many of the accidents occurred during non-routine operations for which the operators were not adequately trained, so they and were not able to recognize the development of abnormal conditions. In some cases the operators, on their own initiative, took actions after the initial emergency evacuation and received significant radiation doses.

Fuel cycle facilities, which process or contain fissile material, need to be evaluated for criticality hazards. The evaluation must show whether the presence of nuclear materials with greater than natural enrichment presents a credible scenario for inadvertent criticality during the processing being conducted at the facility. As regards nuclear criticality, fuel cycle facilities may be split into two groups: (1) facilities where a criticality hazard is not credible, e.g. mining, milling and conversion of natural uranium facilities; and (2) those where the criticality hazards may be credible, e.g. enrichment, reprocessing, uranium fuel fabrication, mixed oxide fuel fabrication, fresh fuel storage (and transport), spent fuel storage (and transport) and waste treatment facilities. Facilities in the second group need to be designed and operated in a manner that provides a high level of assurance that good controls are in place and maintained. The designs of such facilities need to ensure subcriticality in all areas, first by engineering design, utilizing where possible 'criticality safe designed equipment'. The facilities need to be operated in a manner that ensures that excessive amounts of fissile material do not accumulate above the specified limits in vessels, transfer pipes and other parts of the facility. To prevent inadvertent nuclear criticality, process safe operating limits and conditions must be determined and should not be violated. These limits should contain sufficient margin to preclude criticality during any postulated abnormal or accident conditions. Particular attention should be paid to: fissile material in waste streams and storage at the facilities; process changes or modifications which may impact on criticality prevention; fissile material accounting and control procedures; and controls which are used to prevent the accumulation of fissile materials in zones which are not included within the installation's (equipment) design parameters.

In addition to preventing criticality accidents, fuel cycle facilities with credible criticality hazards should make adequate emergency preparedness provisions commensurate to the hazards posed.

2.1.2. Radiation hazards

Radiation safety is an important consideration at nuclear fuel cycle facilities. Special attention is warranted, when developing and using standards and establishing operational practices, to ensure worker safety in the operational process, which may include the open handling and transfer of nuclear material in routine processing. Although external exposures may be limited, potential intakes of radioactive material require careful control to prevent and minimize internal and external contamination and to adhere to operational dose limits. In addition, releases of radioactive material into the facilities and through monitored and unmonitored pathways can result in significant exposures to workers, particularly from long lived radiotoxic isotopes. Some facilities, such as MOX fuel fabrication, reprocessing, and vitrification facilities, require shielding design, containment, ventilation and maintenance measures to reduce potential exposures to workers.

General principles whose effective application will ensure appropriate protection and safety in any situation which involves or might involve exposure to radiation are defined in the IAEA Safety Fundamentals on Radiation Protection and the Safety of Radiation Sources [9]. Based on these principles and objectives, requirements with respect to radiation safety are established in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [10], which are applicable to all types of nuclear installations. However, fuel cycle facilities pose a higher risk to facility operators than to the public, and this fact should be given proper consideration when establishing relevant safety criteria and developing safety guides.

2.1.3. Chemical hazards

Fuel cycle facilities may also pose hazards to workers and members of the public from releases of chemically toxic and corrosive materials. Such facilities may be considered as chemical plants, with construction and operation according to appropriate chemical safety standards. However, major steps in the nuclear fuel cycle consist of chemical processing of fissile materials, which, if not properly managed, may lead to the inadvertent release of radioactive substances.

Chemical hazards differ considerably from facility to facility. The production of uranium hexafluoride (UF_6) involves the use of significant quantities of hydrogen fluoride, which is both a powerful reducing agent and is chemotoxic. This poses a significant hazard to workers, although the hydrogen fluoride is not in itself a radioactive material. Other examples include the use of strong chemical acids to dissolve uranium and other materials and to remove, in some cases, the fuel cladding. These acids are also used to chemically dissolve the spent fuel during reactor fuel element reprocessing, enabling the separation of plutonium and uranium from the residual fission products. In addition, the residual fission products, which comprise approximately 99% of the total radioactivity and toxicity in the spent fuel, pose a significant radiological hazard in what is typically a complex chemical slurry. During the solvent extraction processes, strong acids and organic solvents are used to remove plutonium and uranium from the slurries. These processes can generate toxic chemical by-products that must be sampled, monitored and controlled. Other chemicals encountered at fuel cycle facilities in significant quantities include ammonia, nitric acid, sulphuric acid, phosphoric acid and hydrazine. It is important to recognize that unplanned releases of these chemicals may adversely affect safety controls. For example, a release of hydrogen fluoride could disable an operator who may be relied upon to ensure safe processing.

Chemical hazards have caused operational problems and accidents at many facilities worldwide. The chemical toxicity hazards associated with UF_6 processing were evident in two accidents in 1986 in the USA and Germany [3].

The chemical risks in fuel cycle facilities are integral to nuclear processing. Assurance of safety requires control of both chemical and nuclear hazards. This close relation between these hazards needs to be covered in the safety standards, design and operational measures and process procedures.

2.1.4. Fire and explosion hazards

Many fuel cycle facilities use flammable, combustible and explosive material in their process operations, such as a tributyl phosphate-dodecane mixture for solvent extraction, bitumen for conditioning radioactive wastes, hydrogen in calcining furnaces and chemical reactors for oxide reduction. Some flammable and explosive substances may also be generated as bypass products in the production process or as a result of fault operation when unexpected chemical reactions take place.

Fire and explosion hazards have been recorded at fuel cycle facilities. In 1990, for example, there was an ammonium–nitrate reaction in an off-gas scrubber at a low enriched uranium (LEU) scrap recovery plant in Germany which injured two workers and destroyed the scrubber [3]. Fire is an especially significant accident scenario because it can be both an initiating event for the accident sequence and can disrupt safety systems. It can also provide an energy source to transport radiological and chemical contaminants into uncontrolled areas where they may pose risks to both workers and members of the public. An example of this is the fire and explosion at the Tokaimura reprocessing plant in Japan in March 1997, which contaminated 37 workers with radioactive material.

The design of the facilities should provide for minimum inventories of combustible materials and should ensure adequate control of thermal processes and ignition sources to reduce the potential for fire and explosions. For example, extreme care should be taken to prevent the accumulation of radiolytic hydrogen, which is generated in high activity waste tanks in fuel reprocessing plants. In addition, fire can become a motive force for significant releases of radioactive and toxic material from the facilities. Consequently, fire detection, suppression, and mitigation controls are usually required.

A fuel cycle facility design and its operation should consider the radiological and other consequences from fires and explosions. Suitable safety controls should be instituted to protect against the potential consequences of fire and explosive hazards. These safety controls should be designed to provide the requisite protection during normal operations, anticipated operational occurrences and credible accidents at a facility. Similar to the chemical hazards, fires and explosions which might adversely affect any nuclear safety measures should be given adequate consideration.

2.2. MANAGEMENT ISSUES

Good quality management includes the development, implementation and maintenance of an adequate quality assurance programme, which describes how the work is to be managed, performed and assessed. It is important to recognize that all work is a process that can be planned, performed, assessed and improved in order to enhance facility safety.

2.2.1. Maintenance and modifications

Although fuel cycle facilities all require some degree of maintenance for operation and safety, the maintenance of such facilities as vitrification, reprocessing and MOX fuel fabrication plants requires special care during design and operation due to the expected high radiation or toxic hazards present and the required use of hot cells and glove boxes for some maintenance operations. In addition, maintenance may in itself pose special hazards because it may lead to an initiating event for accident sequences if it is not performed in an adequate manner.

Maintenance measures are normally performed at a facility on a continuing basis, with emphasis on the equipment needed for safety, to ensure that the equipment is available and able to perform its functions, including those required to prevent accidents or mitigate the consequences of accidents, when needed. Most facilities have commitments relative to how equipment required for safety is inspected, calibrated, tested and maintained to the level commensurate with the equipment's importance to safety, to ensure its ability to perform its safety functions.

A facility maintenance programme should generally address the following maintenance activities: corrective maintenance; preventive maintenance; surveillance and monitoring; and functional testing. Adequate management of maintenance activities is essential for ensuring the safety of fuel cycle facilities and for addressing ageing phenomena.

Nuclear fuel cycle facilities may be modified many times during their life cycle. Changes in design or operation are implemented for many reasons, including the need to increase production, improve product quality, allow handling of a different feed material, adjust plant facilities to accommodate new regulatory requirements or reduce or alter the resulting waste or by-product stream.

It is well known from experience in many facilities that incorporating design or operational modifications can result in unforeseen outcomes with complicating adverse effects on health and safety. Such effects may be due to the introduction of new hazards, to variations in existing hazards or to changes in risks or consequences from existing hazardous conditions. In some cases a change to one part of a facility can result in a corresponding hazard increase in another part of the facility which may not be adequately analysed or constrained. In the light of these possibilities, to ensure safe operation of fuel cycle facilities it is important that a good management system is in place to control the planning and implementation of any design or operational modifications.

Modifications at fuel cycle facilities are typically controlled to ensure consistency amongst the facility design and operational requirements, the physical configuration, and the facility documentation. Many fuel cycle facilities have in place a formal documentation process which governs the design and continued modification of the site structures, processes, systems, equipment, components, computer programs, personnel activities and other supporting management oversight activities. These documentation processes typically provide reasonable assurance for the disciplined documentation of: engineering, installation and commissioning of modifications; the training and qualification of affected staff; the revision and distribution of operating, test, calibration, surveillance and maintenance procedures and drawings; post-modification testing; and readiness review.

2.2.2. Human factors

The production processes of most fuel cycle facilities are designed and exercised in a manner which involves an extensive human–machine interface. The operator's 'hands on' involvement in the production process is typical for such facilities. Human factors need to be considered for fuel cycle facilities to alleviate potential safety issues at all stages of the facility's life. Since most of the abnormal operational occurrences at fuel cycle facilities result from human error, human factor considerations are of paramount importance during fuel cycle facility operation. This is particularly true when technology changes are introduced or when equipment modifications are performed. The practices for the formal licensing of fuel cycle facility operators differ from country to country, but it is recognized that an adequate authorization process should be in place to ensure that the operational staff has the proper qualification to perform the work in a safe manner.

A central aspect of human factors is the training and qualification of the personnel who operate fuel cycle facilities. The scope and extent of the training programme for a fuel cycle facility should be related to the safety issues encountered at the facility. However, in comparison with the training programmes established for personnel at NPPs, the training practices for operators at fuel cycle facilities in some countries are weak. Some lack a systematic approach in the development and application of training programmes for the particular facilities, and when modifications are made inadequate procedures are in place for staff training. Human factors should also be taken into account when developing operational and safety procedures, and the wider ergonomic factors of the working environment such as labelling, access, lighting, temperature and user interface design also make an important contribution to reducing the likelihood of human error. The establishment of a good safety culture is considered an important factor which contributes to the safe operation of all types of fuel cycle facilities. Recent experience in this field for NPPs has shown that implementation of a good safety culture can result in significant safety improvements. It is evident that further work is necessary to set out and promote a safety culture philosophy through the whole fuel cycle.

2.2.3. Emergency preparedness

Although the consequences of potential accidents are in general less severe for fuel cycle facilities than for NPPs, consideration should be given to the establishment of adequate emergency preparedness for fuel cycle facilities as well.

In spite of all precautions that are taken in the design to ensure operation without undue radiological or other hazard to the general public, the remote possibility of failures or conditions leading to an emergency situation cannot be excluded for some facilities. The operating organizations therefore should make efforts to carefully analyse hazardous situations, identify the ways in which accidents can develop and estimate the potential consequences to the workers and the public. Adequate emergency preparedness provisions, commensurate with the hazards posed by the particular facility, should be made. Emergency plans for a fuel cycle facility site, which poses significant hazards, should be prepared to cover all activities planned to be carried out in the event of an emergency. Emergency exercises and drills should also be performed, as necessary.

2.2.4. Decommissioning strategy

As a way of allaying concerns about the safety of facilities that are no longer in use, it is desirable to decommission these plants in a timely manner. Although there can be some benefits, in terms of reduction of the collective exposure of the workers, from delaying decommissioning to allow radioactive decay after shutdown at facilities with a high concentration level of short and medium half-life beta and gamma emitters, deferral of decommissioning is generally not the preferred approach for nuclear fuel cycle facilities. One particular concern with delaying decommissioning is that with time operators may lose institutional knowledge about the design of the facilities as well as knowledge of the location and extent of facility contamination. This is especially pressing for process operations that have been shut down or are in standby mode for a decade or more prior to the onset of decommissioning, unless complete and accurate records have been preserved for use in planning and carrying out decommissioning.

2.2.5. Integrated fuel cycle infrastructure

There is a strong interdependence between the facilities that comprise the nuclear fuel cycle. The products of one facility become the feed material for other facilities later in the cycle. This is illustrated, for example, by the transfer of spent nuclear fuel from a reactor to storage facilities, and then to reprocessing facilities. In a similar manner, waste generated from fuel cycle facilities should be stored at the site or transferred to other waste treatment and storage or disposal facilities. There are safety concerns related to the use of residue storage at the site and accumulation of large quantities of radioactive waste with different properties and characteristics. The interdependence mentioned above is very evident in high level nuclear waste, where a licensed disposal site exists. This, together with a very limited capacity to dispose of low and intermediate level wastes, has resulted in a need to extend the temporary storage time and capacity for spent fuel and radioactive wastes in many countries.

Although short term storage of these materials may be safely accomplished, extended storage of the materials poses a range of safety concerns. These include storage container degradation and long term inspectability, contamination control, environmental contamination, hydrogen generation, criticality control and spent fuel degradation. A related concern is that uncertainty about future disposal technologies and facility designs has delayed the selection of acceptable disposal containers. This delay has resulted in the continued storage of radioactive wastes in containers beyond their original design and operational lifetimes.

2.3. SAFETY ASSESSMENT

A well performed and adequately documented safety assessment of a nuclear facility will serve as a basis to determine whether the facility complies with the safety objectives, principles and criteria as stipulated by the national regulatory body of the country where the facility is in operation. International experience shows that the practices and methodologies used to perform safety assessments and periodic safety reassessment for fuel cycle facilities differ significantly from county to country. Most developing countries do not have methods and guidance for safety assessments prescribed by the regulatory body. Typically, the facility safety evaluation is based on a case by case assessment. While conservative deterministic analyses are predominantly used as a licensing basis in many countries, recently probabilistic safety assessment (PSA) techniques have been used as a useful complementary tool for supporting decision making on safety matters.

In 2000, the IAEA developed a technical document [11] on procedures for conducting a PSA for non-reactor nuclear fuel cycle facilities. The main emphasis in this guidance is on the general procedural steps of a PSA specific for a non-reactor nuclear facility rather than the details of the specific methods. The report is intended to assist technical staff managing or performing such PSAs and to promote a standardized framework, terminology and form of documentation for these PSAs. It is understood that the level of detail implied in the tasks presented in this document is not necessary for all fuel cycle facilities or PSA applications. In fact, it is anticipated that for many facilities, a 'streamlined' or 'simplified' interpretation of the information presented in this document will be acceptable. The appropriate level and form of streamlining is dependent upon the specific objectives of the analysis and the magnitude of the hazard that the facility represents. Facility hazard can drive the depth of analysis, as it may well be appropriate to analyse a lower hazard facility to less depth than higher hazard facilities (i.e. the depth of analysis is commensurate with risk). Thus, the concept of hazard graded depth of PSA analysis is considered to be appropriate for fuel cycle facilities. However, worldwide experience gained in the use of PSA to assess the safety of fuel cycle facilities shows that in general there is a lack of facility specific data typically required for quantification of PSA models. In addition, the generic component reliability data relevant to these types of facilities is also extremely limited due to the diversity of facilities.

The NRC recently published a guide on integrated safety assessment (ISA) [12], which is to be used to identify: potential accidents at fuel cycle facilities, the items to be relied upon for the prevention or mitigation of these accidents, and the appropriate measures to ensure that those items would be available and perform reliably if called on to operate. Some other countries are also applying integrated approaches to evaluate the hazards of different natures (e.g. nuclear, radiation, chemical, fire) and their possible combined adverse consequences to the workers and public.

2.4. INTERNATIONAL EXCHANGE OF OPERATIONAL EXPERIENCE

The safety of the nuclear fuel cycle is to some extent mirrored by the results of operating experience during the past fifty years. A recent review of the list of events in OECD NEA Member Countries from 1992 to date, taken from the 'Fuel Incident Notification and Analysis System' (FINAS) database, indicates that there have been more than 90 events reported at fuel cycle facilities [13]. The number of events reported under this system is much higher compared with the number of events reported under the IAEA INES system due to the fact that INES contains only events which might be of interest to the general public, whereas FINAS includes information on any operational event reported to be of safety importance.

To review the causes, recovery and corrective actions and lessons learned from the 1999 criticality accident at the JCO facility in Tokaimura, Japan [14], the OECD NEA held a workshop on the safety of the nuclear fuel cycle in May 2000 in Tokyo. This meeting proved to be a useful forum for the exchange of information amongst the OECD NEA Member Countries on the technical issues concerning the regulation and safety of fuel cycle facilities and emergency response concepts.

Some statistics on operational events which have occurred in the past at Russian fuel cycle facilities have been reported recently [15], but officially published information on these events is limited.

In 1996, the IAEA published a report [16] on significant incidents in nuclear fuel facilities. The report reviews some 58 selected incidents which occurred from 1944 until 1994. The significant incidents were those of criticality, explosion, fire and release of radioactive materials or contamination, most of which affected workers and the public or caused serious damage to property. For each incident, the report describes an outline of the incident, important consequences and, where possible, root causes, lesson learned and actions taken.

Another aspect which is of current interest to many countries is the possible use of safety performance indicators when assessing the safety of fuel cycle facilities. Recent developments at the NRC and IAEA in this particular area show that the experience gained with the application of safety performance indicators for NPPs can be fairly easily tailored to develop and utilize indicators specific for fuel cycle facilities.

Due to some recent incidents at fuel cycle facilities, many regulatory bodies are currently facing the need to address public concerns on the safety of fuel cycle facilities in the same manner as they do for NPPs. It appears that despite the smaller radioactive source terms for these facilities when compared to NPPs, the public is interested in receiving prompt and comprehensive information on any abnormal operational events at these facilities. It is one of the regulatory body's tasks to help build up public confidence by regulating them such that these facilities are operated to the high standards generally observed in NPPs.

2.5. INTERNATIONAL SAFETY STANDARDS

Regulatory systems used by Member States for nuclear fuel cycle facilities vary from State to State. During an IAEA Technical Committee meeting on the status of regulations for nuclear fuel cycle facilities in Member States, held in May 2000, information on the relevant regulatory practices in a number of countries was compiled showing a range of prescriptive, partially prescriptive and non-prescriptive systems. These examples demonstrate that many countries apply different regimes and methods for the effective regulation of fuel cycle facilities, which might be of interest when revising regulatory practices in other countries. Many Member States are currently evolving their regulatory programmes to respond to lessons learnt from the operation of fuel cycle facilities.

For example, US experience with fuel cycle facilities has suggested the need for enhanced regulations. The rupture of a UF_6 cylinder in 1986 and a near criticality accident in 1991 raised concerns about the control of non-radiological risks and control of facility changes, respectively. Based on these experiences, the NRC, in 1994, initiated amendments to its requirements for fuel processing facilities in 10CFRPart 70 [17]. These amendments, which were implemented by September 2000, adopt a more risk informed, performance based approach to regulation. They emphasize the need for an ISA to identify risks, evaluate the consequences of credible accident sequences, and identify the safety controls and control systems relied upon for safety. Similar amendments are proposed in 10CFRPart 63, which will supersede the requirements for high level waste disposal at the Yucca Mountain site in Nevada. Continued refinement of the requirements in 10CFRParts 40, 50 and 72 is expected as well.

Other countries, notably the Russian Federation, Japan and France [3, 18], have been exploring the need for a more effective and efficient regulatory process, and have recently introduced changes to their regulatory systems which are also affecting the regulatory practices relevant to their fuel cycle facilities.

At the international level several publications on fuel cycle facility safety are available from the OECD NEA. However, these publications have not been designed to serve as safety standards. To present an up to date analysis of the safety aspects in nuclear fuel cycle facilities in its Member Countries, the OECD NEA published a report entitled The Safety of the Nuclear Fuel Cycle [6] in 1981. An updated version was issued in 1993, which is currently under review to include the lessons learned from the recent experience gained with the operation of these facilities.

Although some standards on nuclear criticality safety [19–21] exist or are under development by the ISO, in general there is a lack of international safety standards specific to fuel cycle facilities.

Under the terms of Article III of its Statute, the IAEA has the task of establishing standards of safety for protection against ionizing radiation and to provide for the application of these standards to peaceful nuclear activities. The regulatory related publications by means of which the IAEA establishes safety standards and measures are issued in the IAEA Safety Standards Series. This series covers nuclear safety, radiation safety, transport safety and radioactive waste safety, and also general safety (that is, of relevance in two or more of the four areas), and the categories within it are Safety Fundamentals, Safety Requirements and Safety Guides.

Safety Fundamentals present basic objectives, concepts and principles of safety and protection in the development and application of nuclear energy for peaceful purposes.

Safety Requirements establish the requirements that must be met to ensure safety. These requirements, which are expressed as ‘shall’ statements, are governed by the objectives and principles presented in the Safety Fundamentals.

Safety Guides recommend actions, conditions or procedures for meeting Safety Requirements. Recommendations in Safety Guides are expressed as ‘should’ statements, with the implication that it is necessary to take the measures recommended or equivalent alternative measures to comply with the requirements.

The IAEA’s safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations with respect to their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA.

Over a number of years, the IAEA has developed a comprehensive set of safety series documents, which addresses, in a structured manner, many of the nuclear fuel cycle safety needs identified by Member States. The Safety Fundamentals and many of the Requirements and Guides are, in general, applicable to all types of nuclear installations, including fuel cycle facilities. Some of the IAEA safety standards for NPPs and on radiation protection and radioactive waste safety can also be applied to fuel cycle facilities. However, their adaptation may not always be easy and some of the specific safety concerns for these facilities, as described above, are not adequately addressed, if at all, by NPP standards.

With this in view, and looking for a ‘user friendly’ set of safety standards to address fuel cycle facilities, it was proposed to expand the current IAEA safety standards programme by including one additional Requirements document within the nuclear safety standards structure. In addition, five subsidiary Guides were considered necessary to support these Requirements in order to cover all of the major fuel cycle facilities including: mining, milling and refining; conversion and enrichment; fuel fabrication — uranium; fuel fabrication — MOX; and fuel reprocessing. Although not part of the nuclear fuel cycle, isotope production facility safety concerns were also suggested to be covered by an individual Guide.

The Commission on Safety Standards (CSS), which comprises 16 senior regulators from around the world, discussed during its meetings in 2000 the IAEA Secretariat’s proposal for the development of this limited number of additional standards to address safety in the design and operation of non-reactor fuel cycle facilities.

The proposal was accepted and it was generally agreed that the guidance to be developed should be facility related rather than theme or subject related.

In accordance with the decisions of the CSS, the IAEA Department of Nuclear Safety has developed a new subprogramme on the safety of fuel cycle facilities. This will cover the development of the required standards as well as other complementary activities needed to support the enhancement of fuel cycle facility safety in Member States.

3. PROBLEMS IDENTIFIED AND ISSUES TO BE RESOLVED

3.1. INTERNATIONAL SAFETY STANDARDS

Work is under way by operators and regulators in several countries with the aim of securing improvements in the safety of fuel cycle facilities. However, there is no consensus at an international level on what standards should be applied to the significant number and broad range of facilities being designed and operated in the world. For NPPs, the IAEA's Safety Standards series represents the only international nuclear safety standards developed with consensus. No such standards exist for non-reactor fuel cycle facilities.

It is expected that the safety standards for fuel cycle facilities, planned to be developed by the IAEA in the next few years, will build on international consensus with respect to the safety requirements for different types of such facilities.

3.2. INTERNATIONAL EXCHANGE OF OPERATIONAL EXPERIENCE

It is recognized that an essential factor in ensuring the safety of any nuclear installation is the continuing worldwide exchange and analysis of safety relevant information and data. It appears, however, that with respect to fuel cycle facilities this process is somewhat limited to countries with well developed nuclear power programmes. The lack of records in the international databases on incidents and accidents in other countries does not, of course, mean that operational experience feedback is not considered for the facilities in operation in these countries. However, for maximum benefit to be gained by the international nuclear community, it would be helpful if all Member States provided their operational experience feedback so that any valuable lessons learned can be shared with the wider community.

3.3. HUMAN FACTORS

One of the major differences, as discussed in this paper, between operating and regulating reactors as opposed to other fuel cycle facilities is that there are generally fewer engineered safety features in fuel cycle plants and more direct operator intervention. Thus greater reliance is placed on the management of safety and human factors to maintain the safe operating envelope in these facilities. In recognizing this important difference, it is clear that the training and qualification of the personnel who operate fuel cycle facilities are crucial to safety. The scope and extent of the training programme for such a facility needs to be thorough and systematic and must be closely focused on the safety issues encountered at the particular facility.

3.4. SAFETY ASSESSMENT

The hazards posed by different fuel cycle facilities can vary enormously in both form and magnitude. Clearly the safety assessment required for a small uranium mine will be very different from that required for a large spent fuel reprocessing plant. There is nevertheless a need for adequate safety assessment of all fuel cycle facilities which takes into consideration any hazards they pose, many of which have been mentioned in this paper. The PSA or ISA is used in some countries in assessing the safety of fuel cycle facilities. However, because of the diversity and types of technology in use in these facilities and the accompanying lack of plant specific reliability data, these analyses can have large margins of uncertainty. Thus the results must be used very cautiously and ideally should complement the deterministic engineering analysis. Improvements need to be sought in gathering the information which is needed to feed into the PSAs.

3.5. REGULATORY REGIMES

The safety of non-reactor fuel cycle facilities has come to the fore in recent years. Many countries operate one or more of these facilities and public awareness has been raised and confidence in them lowered, both as a result of incidents and because of the well documented problems of how to deal ultimately with radioactive wastes. The criticality accident at Tokaimura in September 1999 brought into sharp focus on a global scale the importance of avoiding a repetition of such an event. The innate mistrust of the general public of all things nuclear, together with the voracious hunger of the media for sensational headlines, places a great responsibility on governments and their designated regulatory authorities.

4. RECOMMENDATIONS FOR STRATEGIC ACTIONS/PRIORITIES FOR FUTURE WORK

4.1. SAFETY OF FUEL CYCLE FACILITIES

The safety of fuel cycle facilities should be improved by promoting: the establishment and implementation of adequate safety standards; the application of the defence in depth concept in design and operation; the use of better training practices focused on particular safety concerns identified for each type of facility; the introduction of a safety culture philosophy throughout the fuel cycle; and the development and application of ISA techniques and methods for evaluation of the design and operational safety of fuel cycle facilities.

4.2. INTERNATIONAL SAFETY STANDARDS

Member States should contribute to the drafting and review of the new standards on the safety of the fuel cycle included in the IAEA programme for 2002–2003. During the time that these international standards are being developed, expert meetings should continue to be organized on a periodic basis to provide a focus for standards development, and safety services should be performed by the IAEA, if requested by Member States.

4.3. INTERNATIONAL EXCHANGE OF OPERATIONAL EXPERIENCE

The IAEA should continue its work of fostering the international exchange of information on regulatory and safety concerns for fuel cycle facilities. Compiling information on operational events worldwide should be considered and organized in co-operation with the OECD NEA (e.g. operation of the FINAS database jointly with the OECD NEA).

4.4. REGULATORY REGIMES

The regulation of these facilities in some countries could be strengthened by implementing enhanced licensing procedures and inspection practices. Effective and efficient fuel cycle facility oversight programmes should be in place to help build public confidence.

5. QUESTIONS TO THE CONFERENCE

(1) What actions should be taken by the IAEA to enhance fuel cycle facility safety?

(2) What are Member State needs with respect to fuel cycle facilities? Does technical support need to be provided to some Member States, e.g. is it necessary to offer training courses specially designed to address specific safety concerns as identified above for these types of facilities?

(3) How can the capabilities in some Member States be strengthened for regulatory supervision of these types of facilities? Is specific training needed for the regulators? Should activities be designed specially to meet this need?

(4) How can IAEA safety services, developed for the assessment of NPP safety, be adapted to make them applicable to fuel cycle facilities?

(5) Is the available guidance for the safety assessment of fuel cycle facilities sufficient? Is there a need to develop additional ISA guidance for such facilities?

(6) Is it worthwhile to develop a framework of safety performance indicators for these facilities, using the experience gained with the application of such indicators for NPPs? Can these indicators be considered as monitors of the safety trends at fuel cycle facilities?

(7) Is there a need for an additional international event reporting system? If so, can the FINAS database be used as a basis, and can it be operated in co-operation with the OECD NEA, as is the Advanced Incident Reporting System for NPPs?

(8) What kind of documents are needed to provide guidance on how to communicate the decisions of the regulatory body for fuel cycle facilities to the general public? Do any further documents on this subject need to be developed, or should the focus be on providing assistance to Member States in adapting the available IAEA publications on this subject for NPPs?

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Nuclear Fuel Cycle Information System, A Directory of Nuclear Fuel Cycle Facilities, IAEA, Vienna (1996).

[2] SHANI, R., "International Fuel Cycle Information System", The Safety of the Fuel Cycle (Proc. OECD/NEA Int. Workshop, Tokyo, 2000), OECD, Paris (2000).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of and Regulations for Nuclear Fuel Cycle Facilities, IAEA-TECDOC-1221, IAEA, Vienna (2001).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, The Safety of Nuclear Installations, Safety Series No. 110, IAEA, Vienna (1993).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Development of Safety Guides for Nuclear Fuel Cycle Facilities, internal report, IAEA, Vienna (2000).

[6] OECD NUCLEAR ENERGY AGENCY, The Safety of the Nuclear Fuel Cycle, OECD, Paris (1981).

[7] NUCNET, A brief history of criticality, Background No. 11/99/A, (October 1999).

[8] LOS ALAMOS NATIONAL LABORATORY, A Review of Criticality Accidents, 2000, Revision, LANL, Los Alamos, New Mexico (2000).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and the Safety of Radiation Sources, Safety Series No. 120, IAEA, Vienna (1996).

[10] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Procedures for Conducting Probabilistic Safety Assessment for Non-reactor Nuclear Facilities, IAEA, Vienna (2001).

[12] UNITED STATES NUCLEAR REGULATORY COMMISSION, Integrated Safety Assessment, Rep. NUREG-1513, USNRC, Washington, DC (2000).

[13] KAUFER, B., "Overview of fuel cycle safety in NEA Member States", The Safety of the Fuel Cycle (Proc. OECD/NEA Int. Workshop, Tokyo, 2000), OECD, Paris (2000).

[14] COMMITTEE ON THE NUCLEAR SAFETY COMMISSION, The Report of the Uranium Processing Plant Criticality Accident Investigation Committee, Tokyo (1999).

[15] KOLESNIKOV, A., "Russian Regulation of Fuel Cycle Facilities", The Safety of the Fuel Cycle (Proc. OECD/NEA Int. Workshop Tokyo, 2000), OECD, Paris (2000).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Significant Incidents in Nuclear Fuel Cycle Facilities, IAEA-TECDOC-867, IAEA, Vienna (1996).

[17] 10 Code of Federal Regulations, Parts 51 to 199, US Government Printing Office, Washington, DC (1993)

[18] KANAGAWA, A., "Overview of JCO criticality accident and measures", The Safety of the Fuel Cycle (Proc. OECD/NEA Int. Workshop Tokyo, 2000), OECD, Paris (2000).

[19] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Nuclear Energy — Fissile Materials: Principles of Criticality Safety in Handling and Processing, ISO 1709, ISO, Geneva (1995).

[20] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Nuclear Energy — Nuclear Fuel Technology: Administrative Criteria Related to Criticality Safety, ISO WD 14943, ISO, Geneva (in press).

[21] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Nuclear Energy — Nuclear Fuel Technology: Nuclear Criticality Control and Safety of Plutonium–Uranium Oxide Fuel Mixtures Outside of Reactors, ISO WD 14941, ISO, Geneva (in press).

Keynote Paper

REGULATORY ACTIVITIES FOR FUEL CYCLE FACILITIES IN JAPAN

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Abstract

REGULATORY ACTIVITIES FOR FUEL CYCLE FACILITIES IN JAPAN.

Japan promotes nuclear power generation, with 52 nuclear power reactors generating 34.5% of total electricity and 4 units under construction. The nuclear fuels are fabricated at six plants. However, the JCO criticality accident on 30 September 1999 seriously degraded public confidence in nuclear safety regulation in Japan. Residents within 350 m of the site were evacuated. The recommendation by authorities for people to stay indoors affected the daily life of more than 300 000 people. Two workers handling the uranium solution passed away. An investigation showed that JCO routinely did not follow crucial safety procedures. This accident was the worst disaster in Japan. The lessons learned led to a new 'Special Law on Emergency Preparedness for Nuclear Disasters' and an amendment of the 'Reactor and Fuel Regulation Law'. The Nuclear and Industrial Safety Agency (NISA), which is a newly created body under the Ministry of Economy, Trade and Industry, is responsible for the safety licenses of all nuclear installations for energy use, such as enrichment, fuel fabrication, power reactors, reprocessing, radioactive waste storage and decommissioning. There are several nuclear fuel cycle milestones worthy of note. Japan Nuclear Cycle Development Institute (JNC) resumed operation of the Tokai reprocessing plant in November 2000, after the explosion accident occurred at the radioactive waste treatment facility in March 1997. The operation was carried out without any major problems. NISA requested JNC to implement a periodic safety review of the reprocessing plant. The Japan Nuclear Fuel Ltd (JNFL) Rokkasho commercial plant is scheduled to be operational in July 2005. The spent fuel storage pool for receiving fuel assemblies has been in service since December 1999, with construction 70% complete. JNFL also has a plan to construct a mixed oxide (MOX) fuel fabrication plant. It is foreseen that off-site spent fuel interim storage facilities will become necessary in Japan by 2010 to cope with the capacity shortage of the on-site spent fuel pools. It is clear that protection of people's lives and health will be assured only with sound and effective nuclear safety regulation. NISA will continue to support IAEA activities in this area.

1. PRESENT STATUS OF NUCLEAR ENERGY IN JAPAN

Japan is promoting nuclear power as one of the major sources of electricity generation which emits no greenhouse gases. Currently, 52 nuclear power reactors with an output of 45 090 MW(e) are generating 34.5% of all the electricity produced, and 4 LWRs of a capacity of 4660 MW(e) are under construction in Japan. Nuclear fuels are being fabricated at six plants that belong to five different fuel fabrication companies.

2. IMPROVED SAFETY REGULATIONS AFTER THE JCO ACCIDENT

The criticality accident at JCO Co. Ltd on 30 September 1999 seriously degraded public confidence in nuclear energy in Japan, just as did the Three Mile Island accident in 1979 and the Chernobyl accident in 1986. These accidents increased the activities of anti-nuclear movements and raised public concern, even though the Russian RBMK-type reactor is quite different from Japanese LWRs.

In the JCO accident, a local authority directed the evacuation of the residents living within 350 m of the site. Though the recommendation to stay indoors was lifted on the following day and the evacuation of the residents was cancelled two days after the accident, these measures affected the daily life of some 310 000 people. Two workers handling the uranium solution died from their exposure. An investigation showed that JCO routinely failed to follow crucial safety procedures. This accident was the worst disaster in the history of Japanese nuclear energy.

2.1. Safety measures taken after the JCO accident

The JCO accident highlighted the importance of safety management in nuclear industries and effective co-ordination between the central government and local authorities for emergency preparedness. Such lessons led to the establishment of a new ‘Special Law on Emergency Preparedness for Nuclear Disasters’ and the amendment of the ‘Reactor and Fuel Regulation Law’.

2.1.1. Special Law on Emergency Preparedness for Nuclear Disasters

This law stipulates that:

— Nuclear licensees are responsible for nuclear disaster prevention, mitigation and restoration;
— Licensees must prepare and implement emergency action plans;
— Licensees must notify national and local authorities of accidents;
— A national emergency response headquarters headed by the Prime Minister be established;
— A nuclear emergency response headquarters should be set up at off-site centres for effective co-ordination between national and local authorities in the

protection of public safety. Nineteen off-site centres are planned; some of these are under construction.

2.1.2. Reinforcement of safety regulations

The new provisions introduced in the amended Reactor and Fuel Regulation Law cover:

— Training of employees for safety management;
— Compliance with safety rules approved by the regulatory bodies;
— Annual inspections of nuclear fuel facilities by resident inspectors;
— A mechanism for workers to report any safety violation to the authorities.

3. ESTABLISHMENT OF THE NUCLEAR AND INDUSTRIAL SAFETY AGENCY (NISA)

The Japanese Government was reformed on 6 January 2001 in accordance with a law requiring more visible, streamlined and efficient administrative processes. Primary safety regulatory activities are now centralized in the hands of the Nuclear and Industrial Safety Agency (NISA) in the Ministry of Economy, Trade and Industry (METI). NISA took over responsibility for the safety regulation of fuel cycle and waste management facilities from the former Science and Technology Agency and became responsible for the licenses of all the nuclear installations for energy use. The number of NISA staff for nuclear safety regulation was increased from 140 to 260; this included raising the number of resident inspectors from 50 to 100.

The Nuclear Safety Commission (NSC) was placed in the recently formed Cabinet Office, with enhanced authority to support the Prime Minister. NSC's mission is to review the safety examination made by the regulatory body in the licensing of nuclear facilities to confirm that the examination is adequate. The number of secretarial staff was increased from 20 to 100.

4. CURRENT STATUS OF FUEL CYCLE FACILITIES IN JAPAN

4.1. JNC reprocessing plant at Tokaimura

In March 1997, a fire and explosion accident occurred at the low level radioactive waste treatment facility of the reprocessing plant operated by the Japan Nuclear Cycle Development Institute (JNC). JNC has since suspended its operation for three and a half years. During this outage, JNC carried out a safety review and took measures on the basis of up to date knowledge and experience in the nuclear field.

Both the former Science and Technology Agency (which used to be an authority regulating nuclear fuel cycle facilities) and NSC examined the review results and concluded that the review was properly made and that the safety improvements were appropriate. JNC resumed operation of the reprocessing plant in November 2000. The entire campaign was carried out without any major problems. NISA directed JNC to implement a periodic safety review (PSR) of the reprocessing plant.

4.2. JNFL Rokkasho Reprocessing Plant

Japan Nuclear Fuel Ltd is constructing a reprocessing facility in Rokkasho village (in the northern part of Japan), which has a maximum reprocessing capacity of 800 tonnes of uranium per year. The start of commercial operation is scheduled for July 2005. The spent fuel storage pool for receiving spent fuel assemblies from power reactors has been in service since December 1999, after a safety agreement was concluded between JNFL and the neighbouring local authorities. The construction is now 70% complete. Testing using water began in a head-end process building in April 2001. Test operations using spent fuels will start in 2003. NISA will regulate the operation of this plant based on its experience in regulating JNC's Tokai reprocessing operations and by referring to relevant regulations in other countries.

4.3. JNFL MOX fuel fabrication plant

In November 2000, JNFL announced that it would enter into the mixed oxide (MOX) fuel fabrication business to meet the demand of the Japanese electric utilities. The company plans to construct and operate a MOX fuel fabrication plant for Japanese customers with a capacity of 130 tonnes of heavy metal per year; MOX fuel fabrication operations are slated to begin three to four years after the Rokkasho reprocessing plant starts operations.

In early 2001, NSC started discussions on a safety review guide for MOX fuel fabrication plants. NISA also started preparatory work for safety assessment, taking into account the experience gained at the MOX fabrication facilities of JNC at the Monju Fast Breeder Reactor (FBR) and Fugen (ATR) plants, and by referring to relevant regulations in other countries.

4.4. Interim storage of spent fuel

Japanese utility companies have their spent fuel pools inside nuclear power plants. It is foreseen that off-site spent fuel interim storage facilities will become necessary in Japan by 2010 to cope with the capacity shortage of the on-site spent fuel pools. The Reactor and Fuel Regulation Law was amended to incorporate regulations for interim storage facilities. A set of technical requirements for siting, public exposure and cask integrity for interim spent fuel storage was prepared by the predecessor of NISA in December 2000. In January 2001, NSC started discussions to establish a safety review guide for interim spent fuel storage facilities, while NISA, which has been following the NSC discussions closely, has begun preparatory work for the safety assessment and inspection of interim spent fuel storage facilities.

5. CONCLUSION

The Japanese Government is promoting MOX fuel usage in LWRs, in parallel with the construction of nuclear fuel cycle facilities and new power reactors. However, MOX fuel usage has not progressed well mainly because public acceptance of nuclear energy has deteriorated following the sodium leakage accident at the prototype Monju FBR in 1995, and owing to other incidents involving nuclear installations. Furthermore, the residents of a small village near Japan's largest nuclear plant voted against the use of MOX fuels in June 2001. This referendum is not legally binding, but its outcome has brought further delays to the use of MOX fuel in LWRs. The Japanese Government and all utilities are trying to regain public confidence in nuclear activities by negotiating with local authorities, since utilizing MOX fuel in LWRs is essential for the implementation of the Japanese nuclear fuel cycle policy.

The protection of people's lives and health will be assured only with sound and effective nuclear safety regulation. For this reason, the Japanese Government will continue to support IAEA activities such as the: exchange of operational experience; creation of safety standards for reactors and fuel cycle facilities; and dissemination for the peaceful use of nuclear energy in the world. Similarly, Japan will collaborate with other countries in accordance with multilateral and bilateral agreements, and utilize technical support organizations such as NUPEC and JAERI for the purpose of assisting in implementing the aforementioned activities.

Keynote Paper

APPROACHES TO REDUCTION OF RISKS AT NUCLEAR FUEL CYCLE FACILITIES

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Abstract

APPROACHES TO REDUCTION OF RISKS AT NUCLEAR FUEL CYCLE FACILITIES.

The paper contains a brief analytical overview of incidents at nuclear fuel facilities; a description of the most hazardous factors that cause these incidents; a probability calculation for accidents of various categories; data on the accident risk structure and the guidelines for risk assessment; and recommendations to ensure accident prevention at fuel cycle facilities.

1. INTRODUCTION

Inherent in radiochemical production are the hazards of electric power facilities such as fire, explosions and general toxicity, and specific hazards such as radiation effects. In view of the far-reaching development of atomic power engineering in the Russian Federation and worldwide, the volume of nuclear fuel fabrication and utilization is likely to increase in the near future. Hence, the possibility (probability) of risk, both individual and collective in nature, and of territorial and social repercussions might be enhanced.

2. ANALYTICAL OVERVIEW OF INCIDENTS AT FUEL CYCLE FACILITIES

The factors that determine hazards in the production of radiochemicals are well known. These are:

- Generation of explosive/fire risk gas mixtures;
- Chemical effects that are accompanied by the generation of heat;
- Formation of deposits that contain fissile materials and organic components;
- Spontaneous ignition;

— Uncontrolled accumulation of nuclear materials in the organic phase;
— Accumulation of nuclear materials in air ducts;
— Utilization of equipment with geometric features that can cause a spontaneous chain reaction;
— Discharge of radioactive effluents into open waters;
— Release of nuclear materials as a result of equipment seal failure due to corrosion.

Following the incidents, which occurred within the first years of the operation of fuel cycle facilities, appropriate measures were taken resulting in the in-depth study of the reprocessing technologies and their safety evaluation. A multistage monitoring system to ensure safety in the production of radiochemicals was established. This system led not only to a decrease in the rate of accidents but also to complacency on the part of personnel, who became less vigilant. This loosening of safety consciousness resulted in the incidents that occurred in 1993. To prevent such events occurring in the future, it is important to focus on those aspects that require special attention. For this purpose, it is worth recalling the data reported on incidents at fissile material reprocessing plants in the Russian Federation and the USA. Figure 1 shows that there was a greater number of accidents in the 1950s and 1960s, caused by a lack of knowledge as well as by an underestimation of the physical-chemical nature of production–operation processes.

The causes of these incidents and accidents can be categorized on the basis of the following features:

— The physical and physical-chemical nature of events, i.e. spontaneous chain reaction, nuclear material ignition, thermal and thermochemical processes, radioactive effluent leakage, emission of radioactive gas and of chemically hazardous substances, and fire.
— Process operations. These include: transportation, storage, and reloading; preparation of fuel materials for reprocessing and their chopping, dissolution and solution clarification; extraction, sorption and sedimentation; waste processing and storage; decontamination and filtration of air, sampling and analysis.
— Technical–organizational aspects such as personnel error, equipment failure, poor process design.
— Equipment type, i.e. radioactive waste reprocessing equipment, auxiliary equipment, transport systems.

To facilitate a uniform understanding of the degree of severity of a radiation effect at a nuclear facility, the IAEA and the OECD Nuclear Energy Agency (OECD

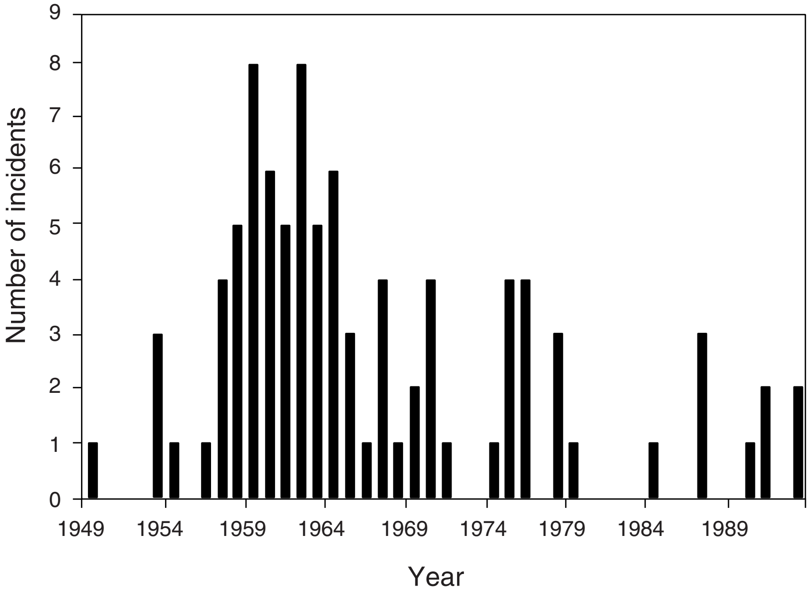

FIG. 1. Distribution of major incidents at radiochemical plants in the Russian Federation and the USA, 1949–1993.

NEA) has developed the International Nuclear Event Scale (INES)[1], that classifies nuclear events on a scale of 0 to 7. When applying this scale to the production of radiochemicals, one should take account of a number of risk factors. These are:

— The potential hazards of the production process,
— The availability of multi-barrier protection,
— The probability of radioactive release into the environment during an accident.

With regard to radioactivity (of up to 10%) released beyond the protection barriers, the following INES levels can be identified:

— Storage of spent fuel in the pit: Level 3,

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, OECD NUCLEAR ENERGY AGENCY, The International Nuclear Event Scale (INES) User's Manual, 2001 Edition, IAEA, Vienna (2001).

— Basic operations, i.e. chopping–leaching, filtration, extraction cycle: Level 5,
— Storage and reprocessing of high level waste: Level 4,
— Storage and reprocessing of intermediate level waste: Level 3.

It is important to note that conversion of fission product activity into the ^{131}I radiotoxicity equivalent involves difficulties. Therefore, the data presented are not absolutely unquestionable.

The purpose of radiochemical plants is to isolate valuable components from irradiated nuclear fuel. Most of the accidents that have occurred at these facilities were caused by radioactive leakage. Of the 25 accidents reported in the Russian Federation, the most severe were classed between Levels 6 and 4 according to INES (Fig. 2).

Figure 3 shows a distribution of these accidents based on the nature of the process. As can be seen from the figure, the most hazardous accidents involved radioactive waste storage, treatment, sedimentation and dissolution.

An examination of the accidents according to technical–organizational aspects (Fig. 4), and the type of equipment used (Fig. 5) allows an understanding of the main causes of the accidents. These are: personnel error and failure of primary and

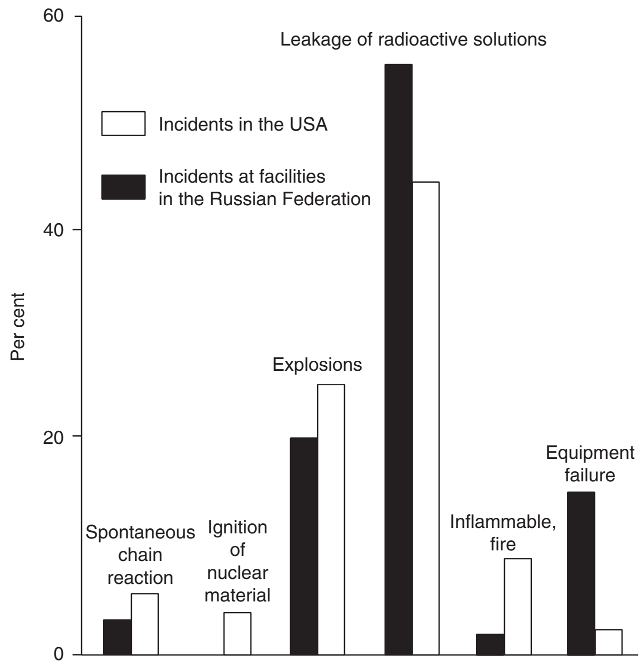

FIG. 2. Classification of incidents according to their physical and physical-chemical features.

equipment. Though quite conditional, an accident probability assessment is very effective in comparing different hazards, and can be used for prediction purposes. Returning to Fig. 1, we see that the accident rate at Russian and US fuel cycle facilities peaked in the late 1950s and early 1960s.

3. ACCIDENT PROBABILITY ASSESSMENT

To assess the accident probability, process structure and personnel preparedness should be correlated. Assuming that a year comprises 300 working days, the incident probability can be estimated as the ratio of the total number of accidents to the number of working days. The assessment of the probability of an event based on the

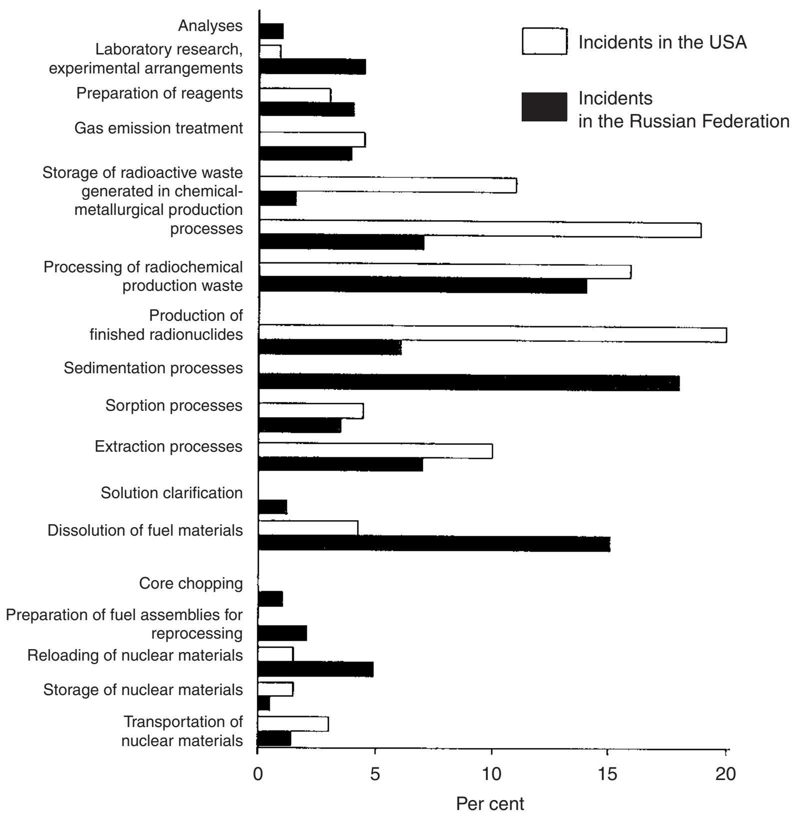

FIG. 3. Distribution of incidents according to the nature of the process.

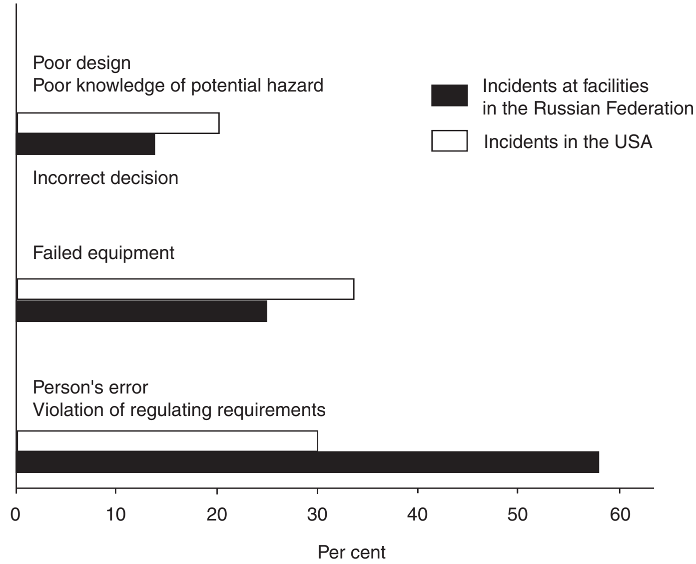

FIG. 4. Distribution of incidents according to their technical–organizational nature.

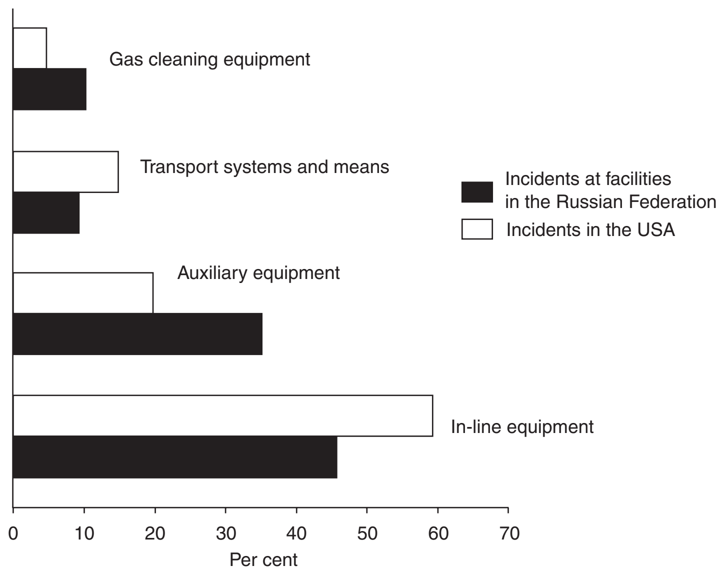

FIG. 5. Distribution of incidents according to the type of equipment used.

TABLE I. PROBABILITIES OF EVENTS OF DIFFERENT CATEGORIES COVERING THE OPERATION OF RADIOCHEMICAL PLANTS WITHIN A PERIOD OF 45 YEARS

Event	Probability
Spontaneous chain reaction	5.01×10^{-4}
Ignition of nuclear materials	1.96×10^{-4}
Explosions	1.59×10^{-3}
Leakage of radioactive solutions	3.41×10^{-3}
Inflammation, fire	3.82×10^{-4}
Equipment failure	6.37×10^{-4}

statistics covering 91 events which occurred at Russian and US radiochemical facilities over a period of 45 years reveals that from 1946 to 1993, the probability decreased by a factor of five in 10 year and 15 year periods.

The probabilities of different categories of events can be estimated as the ratio of a given category of accident to the total number of accidents, which is to be correlated with the number of working days (13 500) over a period of 45 years (see Table I).

Yet another possible approach to the assessment of the probability of an accident is consideration of the causes that increase the accident probability and basically involve the human factor aspect. This approach is rather theoretical, unlike the one described above. Specifically, let us consider the following factors:

- Intentional destructive activities (acts of sabotage and other deliberate violation of operating rules);
- Failure due to personnel error (inadvertent acts, untimely or wrong acts, psycho-physical or emotional unfitness for work);
- Failure due both to the production managers' and workers' lack of professional knowledge.

The following represents an approach to systematize risks and select tasks for the prevention of accidents. Four tasks are selected:

(1) *Assessment of the equipment failure risk related to the latent defects of equipment.* To reduce failure, equipment replacement and change in the process may be required. In such a case it is necessary to calculate the most probable

time of the failure, and estimate the cost of the measures to be taken to clear up the failure. The time can be calculated according to the following equation:

$$\Delta T_{\text{replacement}} = T^{(0.5)}/R$$

where R is the reliability of equipment and T is the probable time of equipment failure.

(2) *Assessment of the risk related to the lack of knowledge of the personnel.* The way out is to set up a special service for personnel retraining. The time after which retraining is required is calculated according to the following equation:

$$\Delta T_{\text{training}} = T^{(0.5)}/R$$

(3) *Assessment of the risk related to a person's error that can be attributed to the intensity and monotony of work, poor lighting, noise and the person's psycho-physical characteristics.*

(4) *Assessment of the risk related to deliberate non-fulfilment of the tasks specified.* The time of the most probable deliberate non-fulfilment of the tasks specified can be determined by external factors.

4. BASIC APPROACHES TO FUEL CYCLE FACILITY SAFETY

Based on the aforesaid, the following is proposed to reduce the probability of accidents:

- — Application of probabilistic safety assessment techniques;
- — Application of control techniques to ensure accident prevention;
- — Determination of the most probable time of equipment failure;
- — Calculation of the time of probable equipment material failure;
- — Determination of a person's professional qualification;
- — Determination of a person's predisposition to committing errors;
- — Calculation of the maximum length of working time after which a person is most likely to commit an error;
- — Calculation of the maximum length of working time after which an external effect is most likely to occur.

Safety in the workplace and in the spent fuel reprocessing zone as a whole is determined by:

- — Availability of services providing safety in spent fuel reprocessing zone;

- Performance of construction and assembly work in compliance with specified norms and regulations;
- Initial testing programmes;
- Process operation schedules;
- Incident prediction;
- Availability of normative documents to ensure proper operation of a facility;
- Preventive maintenance scheduling;
- Radiation exposure survey, surface inspection and environmental control activities;
- Operating instructions and regulations.

Fulfilment of the above conditions made it possible to reduce the accident rate at fuel cycle facilities in the 1990s and, hopefully, will keep them to a minimum in the future.

Lead-in Discussion

ENHANCEMENT OF THE SAFETY OF NUCLEAR FUEL CYCLE FACILITIES

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1. SAFETY OF INB FACILITIES

Some 25 years ago, within the framework of the Brazilian–German Agreement for Peaceful Uses of Nuclear Energy, the Industrias Nucleares do Brasil (INB) (Nuclear Industries of Brazil), as part of the former State owned NUCLEBRÁS company, took charge of fuel cycle activities. In recent years, INB has put into operation three new fuel cycle facilities:

- A uranium mining and milling facility in Lagoa Real/Caetite (State of Bahia) with a production capacity of 400 t U_3O_8/a;
- A uranium UF_6–UO_2 reconversion line for the production of 160 t UO_2/a at Resende, in the State of Rio de Janeiro;
- A pellet production line producing 120 t UO_2/a at Resende.

During this period, the fuel fabrication unit, which had been in operation since 1982, underwent a modernization process to improve safety and increase the production capacity of the plant.

INB is at present constructing a uranium enrichment facility using ultracentrifuge technology developed by the Brazilian Navy. This plant will be built in a modular way and the first stage will produce about 120 t of SWU (separative work units). The first cascade of this stage should be in operation by mid-2002.

Since its founding, INB has given priority to the safety aspects of the operation of its facilities. The design of buildings and installations introduced state of the art devices and procedures required for the safety of the facilities, operators, environment and population.

The problems encountered in other countries at the end of the 1990s, showing that the best safety design and engineered facility could be degraded when safety culture started to decline, brought to the attention of the INB the critical importance of human factors in safety matters. INB followed closely the work performed by the

IAEA and the Brazilian nuclear utility Eletronuclear on assessing safety culture with a view to future adaptation to the fuel cycle front end industry. In 1999, the accident at the Tokaimura fuel cycle facility showed that, if company safety culture started to decline, such an accident could occur even with the best plant design, a complete set of operating procedures and the best trained personnel. INB then considered that the implementation of a safety culture enhancement programme was a high priority.

After an IAEA Advisory Group evaluated, in December 1999, the effectiveness of the operational safety services of the IAEA and recommended that coverage of operational safety services be expanded to include nuclear installations other than nuclear power plants, in particular fuel cycle facilities, INB sought IAEA assistance for establishing a safety culture enhancement programme along the lines of what had been done at Eletronuclear. This project was started in September 2000 and is expected to continue until the end of 2003, when the first part of the programme will be complete.

This effort, a step within the INB's general philosophy that places safety at the highest level, will lead to a continuous internal process of safety culture enhancement, thus fulfilling the INB's most relevant social responsibilities and obligations.

2. ISSUE PAPER QUESTIONS

Using as a background the INB's actions to enhance fuel cycle facility safety, three questions from Topical Issue Paper No. 3 on the safety of fuel cycle facilities must be addressed. The first one is related to actions the IAEA should take to enhance this safety. Fuel cycle facilities for front end and back end operations (both fuel reprocessing installations and REPU and MOX fuel fabrication facilities) are substantially different regarding criticality risk, source term and radioactivity content. When considering IAEA actions to enhance the safety of fuel cycle facilities, the approach should be differentiated for each type of facility. The main concern is to avoid creating excessive regulations for front end fuel cycle facilities that would be mandatory for back end ones.

One of the main characteristics of fuel cycle installations is the extensive reliance on operator performance. Personnel training, including some knowledge of criticality mechanisms and related nuclear engineering, is essential even at the technician level. Supervision and management of operation and maintenance should require staff with a higher degree of theoretical and practical knowledge in subjects like nuclear physics, nuclear engineering, radiochemistry and chemical process engineering. The issue proposed for discussion is whether regulators should impose requirements for a comprehensive examination of the operators of the facility, similar to what is currently required from operators of nuclear power plants.

As mentioned, the personnel factor is an important element when a programme for enhancing safety is envisioned. Employees not only ‘interact’ or deal with their technical expertise, but also with their behaviour and attitude toward their work. Thus, the question becomes: should the level of safety culture in an organization that operates fuel cycle facilities be a subject of prime concern and, if so, what efforts should be made to assess and enhance the safety culture of such operating organizations? Should these efforts require supervision of the national regulatory bodies? How should the IAEA assist in this case?

The second question to be addressed is related to the issue of safety performance indicators for fuel cycle facilities. The development of representative safety indicators is a step forward in the monitoring of safety trends. However, nuclear fuel cycle installations, contrary to what happens with nuclear power plants, are extremely diverse in terms of technologies, processes and engineering design. Therefore, very few indicators might be found for a global application. The main challenge then in answering this question is to extract meaningful information from the operational system data.

The last question is related to the need for the development of an additional international event reporting system for nuclear fuel cycle installations. As mentioned, the development of meaningful safety performance indicators applicable to all fuel cycle installations is quite a complex task. In this respect, an event reporting system may be a palliative measure because many situations could mirror similar developments in other facilities. Therefore, the idea to start a programme of co-operation with the OECD Nuclear Energy Agency on the basis of the FINAS database seems to be an excellent initiative for the IAEA.

Lead-in Discussion

RESOURCES FOR FUEL CYCLE FACILITY SAFETY
Some perceptions and ideas for the future

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1. INTRODUCTION

My current position at the Canadian Nuclear Safety Commission (CNSC) is Head of the Uranium Processing Facilities Section in the Uranium Facilities Division, responsible for regulating Canadian uranium processing facilities. These facilities comprise: one refinery, which upgrades uranium ore concentrate to high purity uranium trioxide; one conversion facility which uses that uranium trioxide to produce uranium dioxide and uranium hexafluoride; two natural uranium fuel fabrication facilities, which transform the uranium dioxide powder into fuel bundles for CANDU type reactors; and a small plant which can recover uranium from phosphoric acid. This facility has not produced any uranium since 1987 and is presently shut down.

It is my privilege to guide this Lead-in Discussion for questions 1, 2, 3 and 8 in Section 5 of Topical Issue Paper No. 3, Safety of Fuel Cycle Facilities. I must emphasize, however, that the remarks and suggestions which follow are solely my own. They do not, in any way, represent the views of the CNSC or the Canadian Government. I do wish to thank my colleagues for their help in preparing this statement.

2. OVERVIEW

The questions set out in Topical Issue Paper No. 3 make it evident that the IAEA is evolving its programme for nuclear facility safety, and that it is seeking inputs to help it decide how to proceed with regard to fuel cycle facilities. Our task is to do what we can to produce advice in that respect. To facilitate this process and make it easier to keep the various topics of interest in order during the discussion, a set of diagrams have been developed to provide a visual context. These will be shown at appropriate points in the presentation.

3. CHARACTERIZING THE DECISION MAKING PROBLEM

Figure 1 represents what I perceive as the IAEA's standard approach: it functions as a mechanism for technology transfer — channelling information to operators, regulators and others — through three main processes. These comprise: (1) making knowledge available in Safety Standards Series, Technical Reports Series and IAEA-TECDOC series publications; (2) organizing training courses and conferences; and (3) sending experts to Member States to provide advisory services through OSART, ASSET, ESRS, IPERS, INSARR, ASCOT, IRRT and UPSAT services[1]. The intended outcome of these activities is to change behaviour and performance, and to enhance safety.

To its credit, the IAEA has implemented this approach with respect to non-reactor fuel cycle facilities, although on a smaller scale as compared with reactor safety. It has produced a number of publications, primarily concerning safety in mining and milling operations, organized several conferences, and is currently planning a training course and other publications.

Figures 2 and 3 represent how I imagine the actual state to be: Fig. 2 is an optimistic conception, which implies greater risk; Fig. 3 is a pessimistic one in which more adverse effects are occurring. The key difference in these cases is the limited flow of information through each of the processes from the IAEA to regulators and operators, as symbolized by the thinner arrows in the frameworks as compared with those in Fig. 1. The consequence of this information deficit is that safety is either not given sufficient weight (the optimistic view) or is not given any weight (the pessimistic view) in decision making about facility design, siting, construction, operation, maintenance, modification or decommissioning.

4. EVOLVING THE PROGRAMME — MOVING FORWARD

Four major, interrelated, issues dominate the IAEA's decision making on how to evolve its programme for non-reactor fuel cycle facility safety. These are:

[1] **ASCOT:** Assessment of Safety Culture in Organizations Team; **ASSET:** Assessment of Safety Significant Events Team; **ESRS:** Engineering Safety Review Service; **INSARR:** Integrated Safety of Research Reactors; **IPERS:** International Peer Review Service on Probabilistic Safety Analysis Reviews; **IRRT:** International Regulatory Review Team; **OSART:** Operational Safety Review Team; **UPSAT:** Uranium Production Safety Assessment Team.

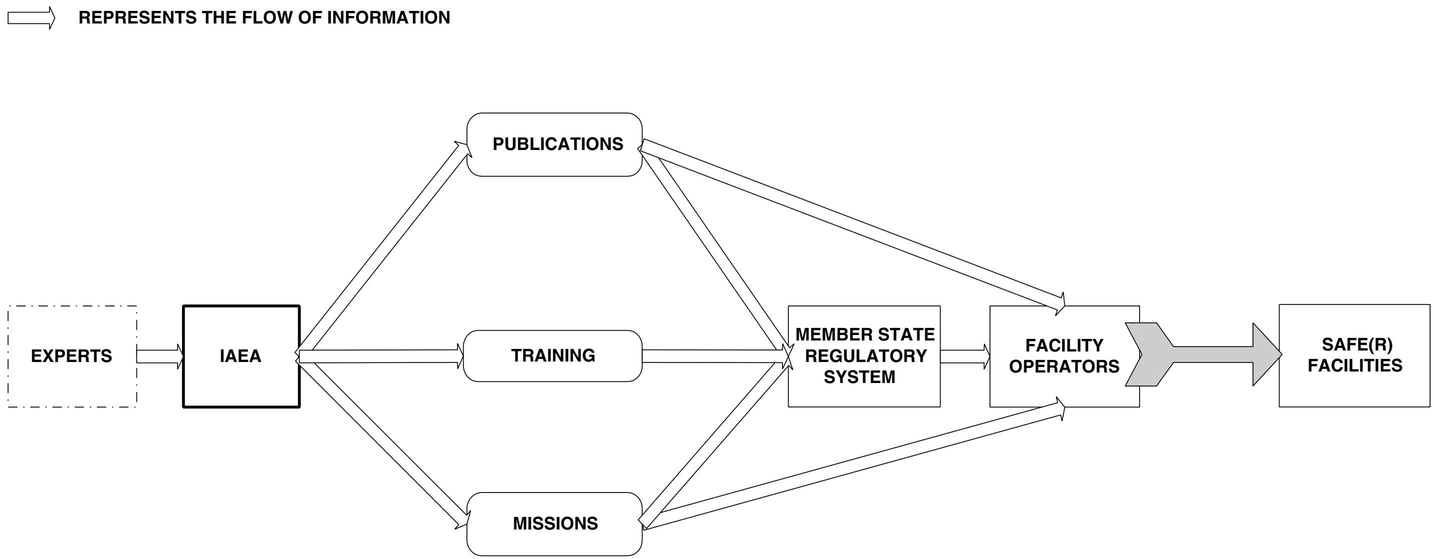

FIG. 1. The IAEA's standard approach.

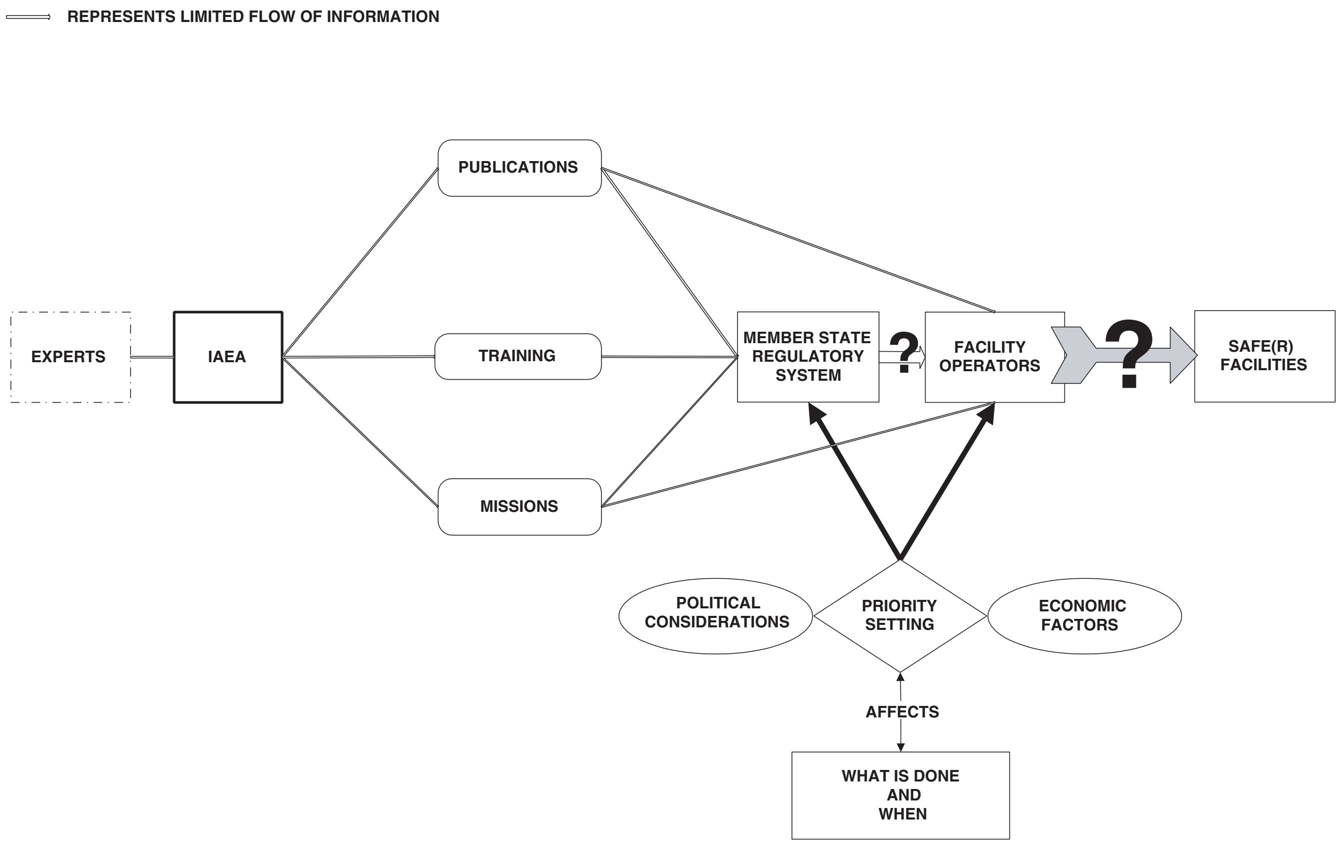

FIG. 2. The current situation.

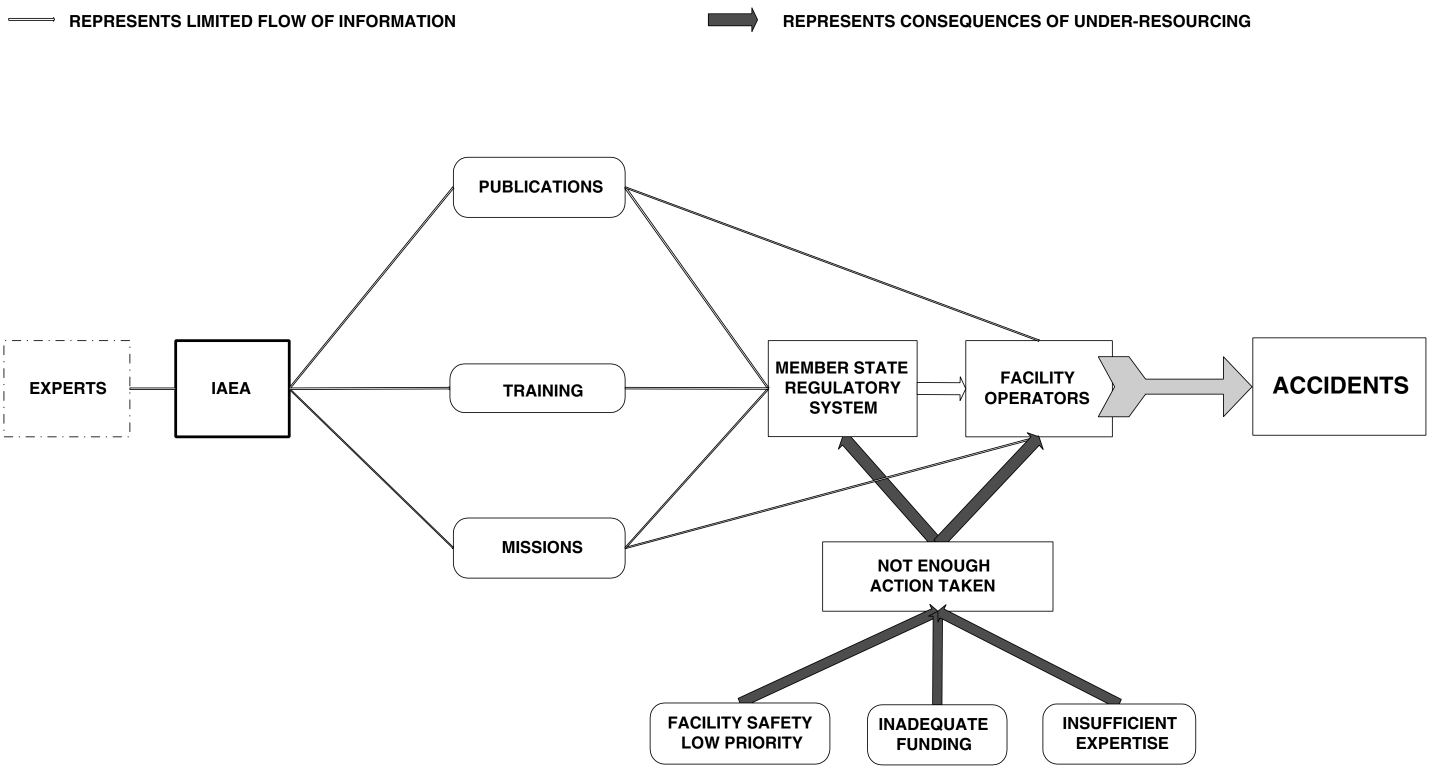

FIG. 3. The real situation.

(1) Member State needs — their magnitude; and (2) what might be done to meet these needs; which leads to (3) setting priorities; that is subject to (4) the availability of resources — expertise and money. The latter aspect will also impact implementation activities in the field by regulators and operators.

It can be expected that Member State needs will be diverse, given the types of facilities, their locations and stage in the life-cycle, from design and siting to decommissioning (see Table I in Topical Issue Paper No. 3), environmental considerations and the various 'safety aspects' as given in Table II in Topical Issue Paper No. 3. In my opinion, that table is not complete: six more 'safety aspects' need to be added to it. These are: human factors, based on the statement made in Section 2 of the Issue Paper, and relative to that safety management systems and safety culture; quality management systems; environmental monitoring; and emergency preparedness.

Thus, a multitude of factors and possibilities will have to be taken into account in planning this programme, such as, should attention be focused on resolving current problems or in trying to prevent future ones by performing environmental assessments? Should the emphasis be on improving facilities, hardware or human performance? Should the focus be on one or more safety aspects, such as safety management and safety culture, which may need to be improved in all types of facilities in many, if not all, Member States? Or should training, for instance, be slanted towards improving regulatory capability rather than operator performance? I am sure the IAEA would welcome some guidance on principles and criteria for setting priorities.

Another aspect of planning that overlaps with resources relates to the difficulties the IAEA typically encounters in obtaining support for new programmes. As a way of mitigating these problems, would the IAEA be able to achieve more vis-à-vis facility safety by 'leveraging' the supply of 'non-traditional resources', as indicated in Fig. 4, rather than limiting its efforts to the standard approach shown in Fig. 1? This is another topic for discussion.

5. CONCLUSION

Altogether, there is a very large number of questions that need to be addressed. The time available for discussing these and formulating advice to the IAEA here today is limited. Let us make the best use of it that we can.

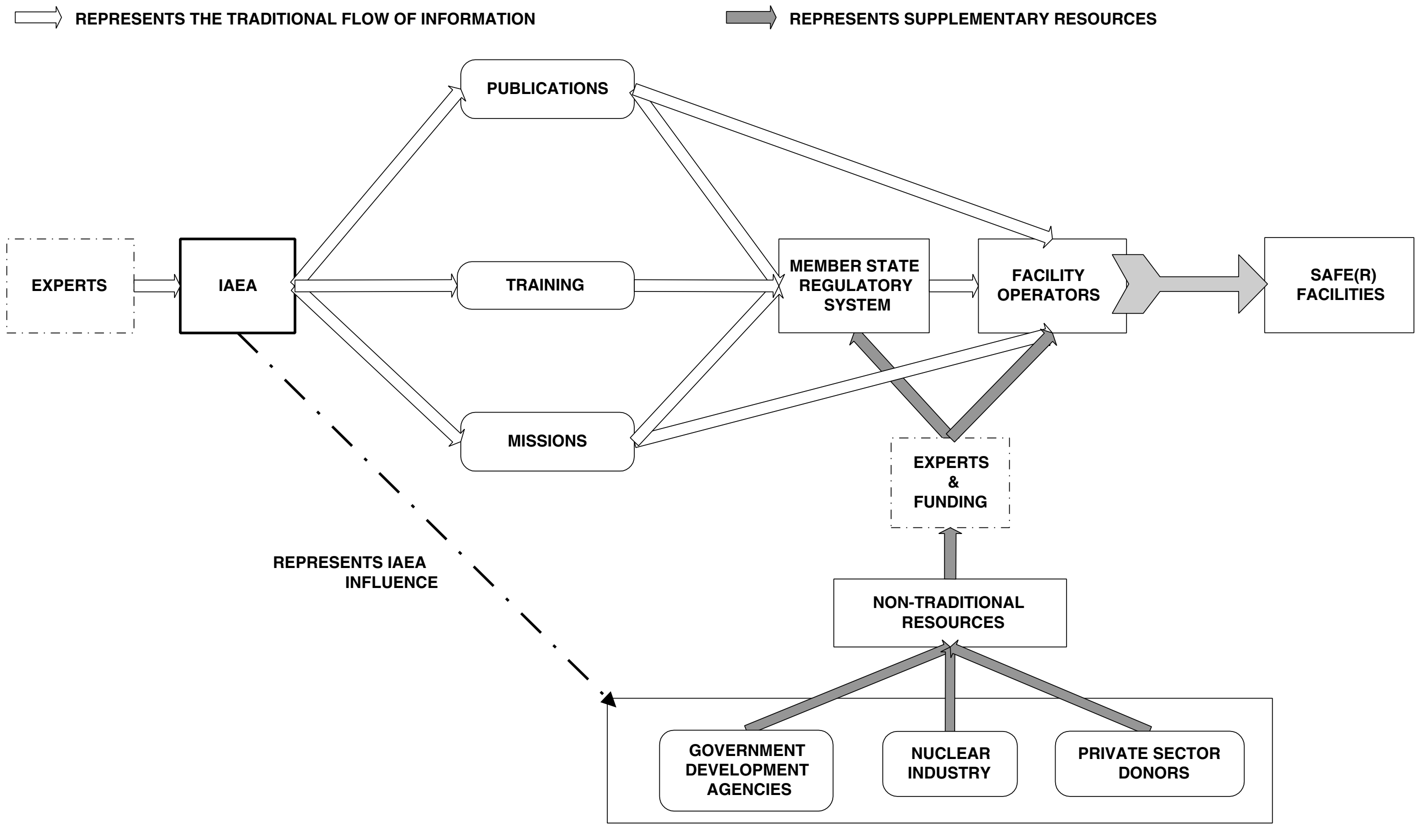

FIG. 4. The future situation.

Lead-in Discussion

CRITICALITY SAFETY OF NUCLEAR FUEL CYCLE FACILITIES

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The criticality hazard is an issue raised more often for fuel cycle facilities than for reactors. In such facilities, nuclear materials are used in different physical and chemical forms, are located throughout the installation and can be transferred or processed. Furthermore, it is hard to contemplate the use of active safety systems, such as those implemented for reactors, to stop an accident situation immediately and automatically. It should nonetheless be emphasized that in reactors the criticality hazards do not only concern the core but also pools and dry fuel element storage areas.

The criticality safety of fuel cycle facilities therefore relies largely on carefully studied means of prevention, based on defence in depth principles, and in-line controls. It also relies on a high level of professionalism of the facility operator, who must ensure the strictest observance of safety rules that are clearly understood by personnel at all levels. Lastly, all the prevention measures implemented must be inspected by an external organization.

More than 60 criticality accidents have occurred around the world, not counting ‘near-by accident’ situations. Today, public opinion is shaken almost as much by a criticality accident as by a reactor accident, whereas the hazards involved are, in fact, quite different considering the inventory of radioactive substances involved. Safety authorities in the different countries concerned and the IAEA have understood public concerns perfectly, particularly in the wake of the most recent criticality accident in Japan. The demand is for more transparency, information and control concerning accidents, even those with limited impact. It is at this price that the nuclear industry will gain acceptance around the world.

As regards past accidents, it can be seen that the causes do not lie in design errors but, generally speaking, in the non-observance of procedures or in human errors. This points to a problem with safety culture, namely inadequate training of operators who have not understood the importance of adhering strictly to procedures, or who are ill-prepared to handle non-routine operations. There now seems to be a better understanding of critical hazard prevention and analysis, largely due to the work of international organizations in proposing safety policies and to the exchange of operational experience acquired by developed nuclear countries.

The initiative led by the IAEA aimed at standardizing safety policies and creating guidance documents should be pursued. In particular, the area of validity of criticality computer codes should be clarified and recommendations made to have such codes qualified using benchmarks. The IAEA could encourage countries possessing experimental facilities to conduct experiments, in conjunction with the nuclear industry and safety authorities, in areas found lacking with regard to safety, for example plutonium based fissile materials with a low moderation ratio. If no qualification exists, safety margins could be recommended.

Training is crucial, as failure to obtain a clear understanding of criticality hazards can lead to drifts that have adverse effects on all parties, or even to degraded situations impairing lines of defence. The IAEA could help to recommend a criticality training programme adapted to all levels, from operators to managers, drawing on the operational experience already existing in different countries.

Lastly, it must be possible to deal with an accidental situation in such a way as to guarantee correct management of emergency preparedness and action plans. This means being able to assess the impact of a criticality accident, estimate the doses received by personnel, detect the accident and rapidly implement the means for action. The project initiated for this new work item, ‘Estimation of nuclear criticality accident fission yields’, can help to meet this demand. In addition, existing facilities capable of reproducing criticality accidents could be used to test equipment and train teams.

With respect to the above mentioned issues, I believe it is important to discuss during this conference what could be done to further improve the safety of fuel cycle facilities and address public concerns in this area. I would like to ask you to share your experience in safety assessment and comment on whether the available guidance on criticality (or in general on safety) assessment is easily available and applied in most of the IAEA’s Member States with fuel cycle facilities. Is there a need for the development of additional guidance or do we need to offer more training in applying the existing ones? As most of you might know, the IAEA provides different types of safety services to assist its Member States in assessing and improving nuclear power plant safety. I would like to ask those of you who have experience with such services to advise on whether we can benefit from a similar service for fuel cycle facilities. Is there a need to assist some Member States in performing independent safety assessments or reassessments of some of the facilities in operation? Can these services facilitate the international exchange of fuel cycle facility operational experience? It is important to know the opinion of the conference on these and similar questions in order to help the IAEA Secretariat to focus its future activities in the field in the right, and possibly most beneficial direction for Member States.

Topical Issue No. 4

SAFETY OF RESEARCH REACTORS

(Session 4)

Chairpersons

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Greece

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Topical Issue Paper No. 4

SAFETY OF RESEARCH REACTORS

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1. RATIONALE

The number of research reactors that have been constructed worldwide for civilian applications is about 651. Of the reactors constructed, 284 are currently in operation, 258 are shut down and 109 have been decommissioned. More than half of all operating research reactors worldwide are over thirty years old. During this long period of time national priorities have changed. Facility ageing, if not properly managed, has a natural degrading effect. Many research reactors face concerns with the obsolescence of equipment, lack of experimental programmes, lack of funding for operation and maintenance and loss of expertise through ageing and retirement of the staff. Other reactors of the same vintage maintain effective ageing management programmes, conduct active research programmes, develop and retain high calibre personnel and make important contributions to society.

Many countries that operate research reactors neither operate nor plan to operate power reactors. In most of these countries there is a tendency not to create a formal regulatory body. A safety committee, not always independent of the operating organization, may be responsible for regulatory oversight. Even in countries with nuclear power plants, a regulatory regime differing from the one used for the power plants may exist. In some countries there is a lack of human resources and expertise for the regulatory body, in comparison with the operating organization, which leads to a lack of efficiency and credibility of the regulatory body. Again, by contrast, some countries have very effective regulatory supervision programmes in place for research reactors.

Concern is therefore focused on one tail of a continuous spectrum of operational performance. The challenge is to implement improvements where needed without an undue adverse impact on well managed operations. Pictorially, the population of research reactors might be characterized as a combination of their operational safety focus and regulatory supervision, as shown in Fig. 1. The desired state is one of a strong operational safety focus monitored by strong regulatory supervision (Zone I). A strong operational safety focus but weak regulatory supervision (Zone II) is not ideal but may be adequate, at least until put to the test. Strong regulatory supervision with a weak operational safety focus (Zone III) is a transient state; the regulator will either insist on improving the facility's operational safety focus or will shut it down. Facilities with a weak operational safety focus and weak regulatory supervision (Zone IV) are the real concern. Unfortunately, certain processes move in that direction. The operator's acceptance of unabated ageing of equipment, loss of staff expertise and underfunding constitutes a shift to the left; the regulator's condoning and acceptance of the same constitutes a shift down; and the combination is a shift of some research reactors into the unacceptable zone.

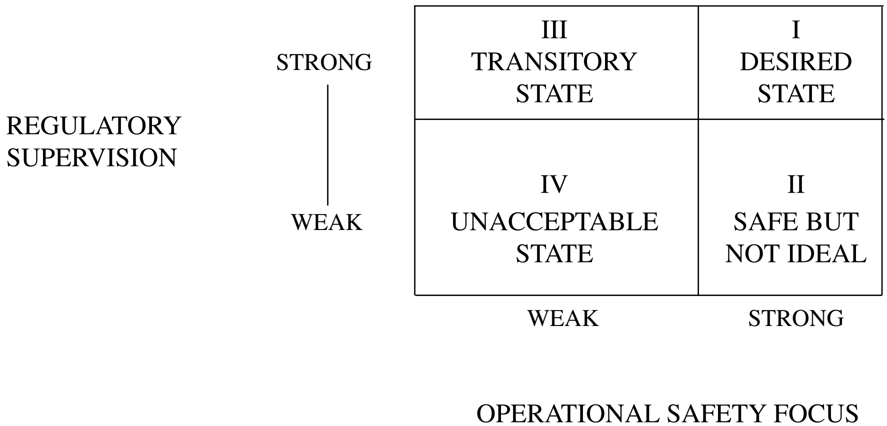

Fig. 1. Research reactor operational safety focus and regulatory supervision.

The 258 research reactors that are no longer operating are in some form of shutdown (hereinafter termed ‘extended shutdown’). Some of these are expected to restart sometime in the future, some are awaiting decommissioning with or without nuclear fuel in the facility and for the remaining reactors there is no clear definition about their future. All these situations present concerns related to safety, and the most frequent concerns are related to the loss of corporate memory, personnel qualification, maintenance of components and systems and the preparation and maintenance of documentation.

Many reactors face concerns with funding for operation; generally, the funding of an appropriate utilization programme is then even more restricted. Frequently the utilization programme shifts from a science based to a profit based programme, and in some cases safety may not remain a top priority.

The number of operating research reactors in industrialized countries has decreased by about one-third in the past 15 years, while the number in developing countries has remained fairly constant over that period. As a result, the proportion of operating reactors in developing countries is steadily increasing while the funding available for operation and utilization in these countries is steadily decreasing.

The IAEA has been sending missions to review the safety of research reactors in Member States since 1972. Some of the reviews have been conducted pursuant to the IAEA’s functions and responsibilities regarding research reactors that are operated within the framework of Project and Supply Agreements between Member States and the IAEA. Other reviews have been conducted upon request. All these reviews are conducted following procedures for Integrated Safety Assessment of Research Reactors (INSARR) missions. The prime objective of these missions has been to conduct a comprehensive operational safety review of the research reactor facility and to verify compliance with the IAEA's Safety Standards. The methods used during an INSARR mission are discussed in Ref. [1]; the results of many INSARR missions have been collected and are analysed in Ref. [2]. Some of the important issues identified are the following:

— General ageing of the facility;
— Uncertain status of many research reactors (in extended shutdown);
— Indefinite deferral of return to operation or decommissioning;
— Inadequate regulatory supervision;
— Insufficient systematic (periodic) reassessment of safety;
— Lack of quality assurance (QA) programmes;
— Lack of an international safety convention or arrangement;
— Lack of financial support for safety measures (e.g. safety reassessment, safety upgrading, decommissioning) and utilization;
— Lack of clear utilization programmes;
— Inadequate emergency preparedness;
— Inadequate safety documentation (e.g. Safety Analysis Report, operating rules and procedures, emergency plan);
— Inadequate funding of shut down reactors;
— Weak safety culture;
— Loss of expertise and corporate memory;
— Loss of information concerning radioactive materials contained in retired experimental devices stored in the facility indefinitely;
— Obsolescence of equipment and lack of spare parts;
— Inadequate training and qualifications of regulators and operators;
— Safety implications of new fuel types.

These issues have been addressed by the IAEA Secretariat and the Chairman of the International Nuclear Safety Advisory Group (INSAG). The INSAG Chairman reported to the Director General "...that in spite of the prompt reaction of the Secretariat …, the problem remains very serious… INSAG has identified three major safety issues that are:

— The increasing age of research reactors,
— The number of research reactors that are not operating anymore but have not been decommissioned, and
— The number of research reactors in countries that do not have appropriate regulatory authorities." [3]

In addition, INSAG has expressed concern with "…the level of safety culture surrounding these reactors. …INSAG considers that adding a Protocol to the Convention on Nuclear Safety to cover research reactors would be a major contribution towards a better, international safety framework for these reactors."

The IAEA's General Conference subsequently passed Resolution GC(44)/RES/14 [4], which:

"1. Calls upon all Member States with research reactors to ensure that those reactors are subjected to strict safety and radiation protection arrangements;
2. Invites the Board of Governors and the Director General of the IAEA to continue to maintain its emphasis on the safety of research reactors, particularly in assisting Member States to implement relevant Safety Standards;
3. Requests the Secretariat to continue to monitor closely research reactors subject to IAEA Project and Supply Agreements, and to assist relevant Member States in fulfilling all relevant safety obligations;
4. Requests the Secretariat, within its available resources, to continue work on exploring options to strengthen the international nuclear safety arrangements for civil research reactors, taking due account of input from INSAG and the views of other relevant bodies; and
5. Requests the Director General to report to it at its forty-fifth (2001) regular session on the implementation of this resolution."

This issue paper discusses the concerns generated by an analysis of the results of INSARR missions and those expressed by INSAG. The topic is timely and important because a large number of research reactors currently face not only these concerns but also the problem of spent fuel disposal following completion of the current US take-back programme and the Russian take-back programme, which is expected to commence in the near future. Many countries will need to make decisions soon on the future of their reactors to take advantage of these spent fuel options.

2. STATUS OF THE TOPICAL ISSUE

Research reactor safety is gaining importance within the general scope of nuclear installation safety worldwide. Generally, all nuclear reactors that do not generate commercially used electricity are considered to be research reactors. This results in a large variety of designs, a wide range of power levels, a wide range of utilization programmes with a broad range of benefits to humanity (e.g. research, training, medical isotope production or commercial services) and different modes of operation for research reactors. Again, the safety concern for research reactors is primarily that subset characterized in the previous section; there are many well operated and maintained research reactors outside the subset of major concern.

2.1. SAFETY OBJECTIVES FOR RESEARCH REACTORS

Despite the differences between research reactors and power reactors, the safety objective is common [5]. However, these differences require flexibility in the implementation of the requirements to achieve the safety objective in research reactor facilities.

The general nuclear safety objective stated in Ref. [5] is “To protect individuals, society and the environment from harm by establishing and maintaining in nuclear installations effective defences against radiological hazards.” This objective for the safe operation of research reactors is expanded in Refs [6, 7]. While Member States may express this objective differently, there is general agreement on the concept.

A justification principle was applied before construction and operation of the reactors currently in existence; that is, each facility had a utilization programme that justified the commitment of resources. That principle should continue to be applied to newly planned and constructed reactors. For reactors that are in extended shutdown with no plans for an ultimate restart, this principle is clearly not met.

The radiation protection objective [5–7] relies on accident mitigation resulting from design measures (e.g. engineered safety features) incorporated into the reactor and in the appropriate emergency plans. As demonstrated by INSARR missions, there are some deficiencies in these areas at some research reactors.

2.2. REQUIREMENTS TO MEET SAFETY OBJECTIVES

In order to achieve these objectives, a number of safety requirements and recommendations have been considered by Member States at the national level and by the IAEA at the international level.

2.2.1. Member States

Many Member States, especially those having nuclear power programmes, have produced laws, regulations, standards and guides for the safe operation of research reactors. In addition, in these States, with a few exceptions, an independent regulatory body administers the regulations and ensures the control of safety at nuclear installations. However, even in Member States with nuclear power programmes the regulation of research reactors is not always thorough and independent.

Some Member States have incorporated the IAEA standards and guidance discussed below into their national regulations. On occasion over the past decade, the IAEA Safety Standards have been incorporated into the contractual requirements of suppliers of new research reactors.

Not all developing Member States have detailed regulations based on legislation. In addition, in developing Member States without nuclear power plants an independent regulatory body may not exist. In these cases a safety committee, independent of the operating organization, may provide the regulatory oversight for the research reactor.

2.2.2. International organizations

The IAEA has produced safety requirements, recommendations and guidance [6–9]. These documents provide worldwide consensus on the topics covered, since international committees prepare them and resolve comments from Member States. These documents are designed to address all safety aspects of research reactor design, operation, utilization and decommissioning. They include, inter alia, items of concern for the IAEA Secretariat, INSAG and the IAEA's General Conference such as regulatory supervision, operation by suitably qualified and experienced persons, safety analysis, utilization, emergency planning, safety culture, quality assurance and decommissioning. As new areas of concern have emerged (e.g. decommissioning, regulatory oversight, quality assurance, safety culture), the IAEA has produced additional consensus documents on these subjects which are applicable to research reactors. As new material is developed that will eventually be incorporated into formal IAEA documents it is made available in draft form; examples of this are recommendations concerning aspects of reactor operation, including commissioning, operational limits and conditions, maintenance, operating procedures, and source term and radiological consequence analysis.

There is general agreement worldwide on these requirements and recommendations for safe operation. However, a wide disparity exists in their application to operating and shut down reactors.

The IAEA has continued to provide safety missions to industrialized and developing Member States to review the application of its standards and guides to individual reactor facilities. These safety missions have been performed at the request of the operating organization or the regulatory body of the Member State. The mission may consist of a full scope INSARR review of the reactor design and operation against the requirements and recommendations of the IAEA documents. Alternately, it may be restricted to the review of a specific topic such the Safety Analysis Report or one or more of its chapters. In addition, the IAEA provides technical assistance to Member States through expert missions on a variety of safety related topics.

Recently, the IAEA has put into operation an Incident Reporting System for Research Reactors (IRSRR). The system is modelled after a similar reporting system for nuclear power plants. Although not all Member States have agreed to participate in the IRSRR, incident reports are being collected and distributed, and meetings were held in 1999 and 2000. Efforts are under way to increase the number of participating countries and to ensure that all events with lessons for safety are reported.

3. PROBLEMS IDENTIFIED AND ISSUES TO BE RESOLVED

The following is a detailed discussion of the problems and issues identified in Sections 1 and 2 for the subset of research reactors as characterized there. Specific actions for the resolution of the issues are recommended in Section 4. Because the problems and issues identified are interrelated, they may be classified according to the five groups discussed below.

3.1. AGEING FACILITIES

Ageing is defined as a general process in which the characteristics of components, systems and structures gradually change with time or use. If unabated, the ageing process eventually leads to the degradation of materials under normal service conditions. These include normal operation and transient conditions under which the component, system or structure is required to operate. Changes in characteristics because of accident and post-accident conditions are not usually considered part of the ageing process and are evaluated on a case by case basis. Physical and non-physical effects can bring about ageing.

Research reactors were generally not designed, constructed and operated for a specific lifetime. If proper preventive and corrective maintenance is performed and obsolete equipment replaced, the reactor facility may operate safely and efficiently for an extended period of time. Maintenance is not a priority in many regions where research reactors are located. A facility in such a culture may be heavily impacted by ageing, whereas the same facility in a different country may not.

In research reactor facilities, the effects of physical ageing such as corrosion may be degradation, which results in the reduction or loss of the ability of components, systems and structures to function within the expected criteria. Typically, the ageing process may reduce the reliability of components, structures and systems. It may reduce the defence in depth and affect the safety of the facility unless preventive and corrective measures have been implemented.

3.1.1. Lack of ageing management

Degradation through ageing is counteracted through a programme of ageing management for appropriately selected components and systems that usually consists of four stages:

(a) The use of a methodology, usually surveillance and in-service testing, that will detect degradation early enough to prevent failure;
(b) The collection of data;
(c) The evaluation of data to determine the extent of degradation;
(d) Corrective actions, usually maintenance, to correct deficiencies.

In some cases, physical and non-physical ageing effects have become so prevalent that it is impractical to correct them individually. This may lead to complete refurbishment of the reactor facility. This is, of course, an expensive process, and lack of financial support and a heavy utilization programme are impediments to refurbishment.

3.1.2. Obsolescence and lack of spare parts

During the lifetime of a research reactor, technological advances will occur that result in the introduction of new components and techniques. This may lead to difficulties in getting spare parts because the component or system is no longer manufactured. In such cases, failure in the obsolescent component can only be remedied by replacement of the entire system.

3.2. DEFICIENCIES IN REGULATORY SUPERVISION

A number of research reactors operate in countries that do not have appropriate regulatory authorities and, therefore, have poor regulatory oversight for both operating and shut down reactors. To have effective regulatory supervision, an adequate infrastructure should be developed which is made up of several components. Inadequacy in any one of them may seriously affect the usefulness of the regulatory regime.

3.2.1. Deficiencies in regulatory infrastructure

A legal framework that defines the subjects covered by the law (or regulation), that appoints the regulatory body and that spells out its responsibilities and authorities is required to ensure that the regulatory body will have the power to exercise its duties and enforce compliance with its decisions.

The regulatory body that is set up under the provisions of the appropriate law must have sufficient staff to carry out its functions, a sufficient budget to maintain this staff on a continuous basis and the ability to solicit external help when necessary. The regulatory body should be effectively independent of the organizations and activities it regulates. Of even greater concern, some countries have no regulatory body at all.

3.2.2. Lack of experience and competence

Often regulatory bodies are so inadequately staffed that they cannot perform periodic compliance inspections and safety reassessments at research reactors. Independent expertise is often not available locally and difficult to obtain internationally. In some cases the regulatory body is not separated at all from the operating organization.

It is clear that the regulatory authority should possess adequate knowledge and experience in matters, both legal and technical, under its jurisdiction. Regulatory bodies in some countries with medium or small reactor programmes or with no nuclear power programme find it extremely difficult to maintain competence and experience in the full range of expertise needed to fulfil regulatory responsibilities. In some countries a newly created or a reconstituted regulatory body has difficulty in establishing its authority over a reactor that has operated for many years without regulatory oversight.

3.3. RESEARCH REACTORS IN EXTENDED SHUTDOWN

A large number of research reactors are in a period of extended shutdown awaiting decisions on their future. There can be many reasons for this extended shutdown, such as lack of funds for operation or utilization, lack of scientific utilization and interest, need for a large investment to provide necessary refurbishment, national political uncertainties, uncertainties in the disposition of the irradiated spent fuel, obsolescence of the facility and lack of funds for decommissioning. Often the decision making authority to restart or decommission is out of the hands of the operating organization and rests with higher levels of government.

3.3.1. Indefinite deferral of return to operation or decommissioning

If not maintained, the safety of a reactor in extended shutdown will deteriorate. Therefore, the reactor must be maintained in accordance with the operational limits and conditions of the operating licence, often amended to reflect the shut down condition of the reactor. In several cases the ownership of and responsibilities for the shut down reactor have not been well established. Members of the operating staff seek other employment and there can be gross evasion of responsibility and loss of knowledge concerning the facility. This can lead to the deterioration of reactor systems and equipment, a loss of safety culture and a consequent decrease in the level of safety.

Two thirds of the reactors that no longer operate have not been decommissioned. The most common reasons for not decommissioning a reactor that is in extended shutdown are the hope that the reactor will be returned to operation and the presumed high costs of alternatives. Research reactors should not be allowed to remain in extended shutdown for a very long period of time. As soon as possible, the operating organization should prepare a long term strategic plan which shows the pros and cons of the options available for the reactor, including decommissioning.

The cost for returning to operation or for decommissioning can be substantial. In some cases research reactors are not restarted after a long period of extended shutdown because of the costs of refurbishment and the obsolescence of the reactor and experimental equipment. Experience has also shown that these reactors are rarely decommissioned promptly because of the perceived high costs of decommissioning, which have often been overestimated. As more and more reactors are decommissioned, the true costs will become evident. It should be noted that IAEA funds have not been provided for decommissioning.

The technology for decommissioning research reactors is well established, as demonstrated in Ref. [10]. The first step in the decommissioning process is the removal of nuclear fuel from the facility. This is often a problem for the operating organization because there is no facility to receive the fuel. If the fuel must remain at the reactor facility after shutdown and decommissioning, provision must be made for its safe storage. Facilities considering removal of nuclear fuel are well advised to do so when the opportunity exists. Until May 2009, the USA will be accepting spent research reactor fuel of US origin that has not been irradiated beyond May 2006. The Russian Federation is expected to initiate a similar programme in the near future.

3.4. INADEQUACIES IN THE OPERATING ORGANIZATION MANAGEMENT

Among the issues which require attention relating to the operation of research reactors are those associated with responsibilities in management (staffing, training and retraining, quality assurance, safety culture), long term planning, safety review of operation through self and peer reviews, emergency planning and the safety of experiments.

3.4.1. Loss of expertise and corporate memory

Responsibility in management requires that there is sufficient staff with appropriate levels of education and training to ensure safety. Knowledgeable personnel are retiring at many research reactors. In addition, experienced personnel at research reactors often seek more attractive employment elsewhere. This results in a loss of expertise and corporate memory. Compounding this is the difficulty in recruiting knowledgeable and experienced replacement personnel because of the decreased number of students in the field and the competition among facilities for competent individuals. Funding to cover the overlap between outgoing and incoming personnel is rarely available.

While most facilities provide adequate initial training for their staff, retraining (continuous training or re-qualification) is not widely utilized to maintain efficiency and effectiveness.

3.4.2. Inadequate QA programmes and safety culture

While most research reactors incorporate some aspects of quality control in their operation, few low and intermediate power level reactors incorporate a complete QA programme based on national or international guidelines. Recognition of the need for a QA programme for these reactors is a recent development at most reactors. Reactor managers need to be shown that a QA programme graded to the needs of the facility will be an effective and time saving management tool. They also need to recognize that safety must be ‘grown’ into an organization and not be seen as a product of regulatory compliance.

One concern affecting all safety issues is the level of safety culture surrounding a research reactor. In many cases, the concept of ‘safety culture’ is new and perceived as being qualitative because of the difficulties in defining the concept and demonstrating its existence. Operating organizations often have not taken advantage of the guidance literature on the subject. The lack of properly trained staff, the loss of institutional memory through staff attrition and inadequate regulatory supervision are all human factors that contribute to a lack of safety culture and therefore safety.

3.4.3. Insufficient financial support

The lack of financial support is the greatest problem facing research reactors. In the past, a budget was often provided by a governmental agency. Presently, many of these same facilities are required to generate income to support their programmes, even though the facility staff lacks experience in techniques to generate income, the facility cannot provide profitable services or there is a very limited possibility of contacting commercial companies. Except for operating budgets, strategic utilization plans that match and promote resources with the needs of the user community have not been extensively utilized by operating organizations.

3.4.4. Inadequate emergency preparedness

In some research reactors, especially those with intermediate power levels, emergency plans and preparedness are inadequate. Procedures are not well demonstrated because drills and exercises are seldom conducted.

3.4.5. Lack of strategic long term planning

Strategic long term planning in the management of the reactor is inadequate at many research reactors and may jeopardize reactor safety. Such planning has become essential, especially at those reactors that are now required to generate some of the funds for operation. These funds can only come from utilization. In the absence of these funds there will be a shortfall in the available operating budget.

Most reactors constructed in the past were considered multipurpose reactors in that they would support utilization programmes in many technical disciplines. From a practical point of view, however, an individual reactor facility cannot usually support programmes in all areas. To generate income it is therefore necessary for the facility to specialize in areas where there is a need and where the facility has appropriate technical and human resources. The generation of a strategic, long term plan matching the needs of the experimental community, the capabilities of the reactor and the financial resources available has become indispensable for the successful operation of a reactor.

Even if the reactor management cannot meet the quota for its portion of the operating budget, the safety of the reactor cannot be allowed to deteriorate. In this case the operating organization must provide the funding for maintaining the safety of the reactor.

3.4.6. Lack of systematic reassessment of safety

The existence of up to date safety documentation (a Safety Analysis Report) is important to ensure that all safety issues at a reactor have been considered. Recently, through the efforts of Member States and the IAEA, some research reactors have produced or are in the process of producing a current Safety Analysis Report. These reports consider changes in the reactor site, new operating modes, new forms of utilization, modifications and the use of new fuels. Many research reactors still have outdated, superficial or incomplete Safety Analysis Reports that should be improved.

Reassessments of safety have traditionally occurred at research reactors at the time of major upgrades, modifications, installation of safety significant new experimental facilities and at licence expiration and renewal. Reassessments of safety have recently accompanied the backfit preparation of a new Safety Analysis Report at many facilities. In the absence of these motivations, however, there has been little inclination at research reactors to periodically reassess safety. In the meantime, the configuration of the reactor may have changed significantly through a long series of individually minor changes.

An area of reassessment needing special attention is the siting of existing reactors. In many cases, the land use and other siting factors around the reactor facility have dramatically changed, requiring that the suitability of the site be reassessed against the current configuration and operational mode of the reactor. One important issue for the safety of old operating research reactors is the difficulty of verifying the facility's resistance against earthquakes, especially if the seismic spectrum has been updated and the accelerations increased due to improved knowledge of the site characteristics. This difficulty is due mainly to the uncertainties concerning the mechanical resistance of the old buildings and to the lack of knowledge concerning the eventual corrosion of the iron reinforcement inside the concrete. It is very important to reach an international consensus and to adopt a clear and justified approach on this subject. Such an approach may be based on the inventory of radioactive materials, on the duration of the reactor operation and on the various risks associated with the facility. In the future, a probabilistic safety analysis may be expected in the Safety Analysis Report of a research reactor, but the state of the art does not support it as being a requirement at this time.

Peer review is an area of co-operation being promoted by the IAEA that has not reached its full potential. A peer review may take many forms. Such reviews are offered in some countries for domestic reactors. For example, a peer review, especially at a reactor facility facing regulatory compliance issues, may speed the return to full compliance. In other cases, peer reviews may be performed in order to show that the reactor is operated based on internationally recognized practices. A peer review may be organized at a reactor facility using a group of local science and engineering professionals who are not members of the operating organization. Finally, a peer review may be an INSARR mission organized by the IAEA at the request of a Member State.

The practice of self-evaluation for the reassessment of the safety of a research reactor is also encouraged by the IAEA and is becoming more widespread. A reactor that is to undergo a peer review may wish to perform a self-evaluation in order to compare the results of the two reassessments.

3.5. INADEQUATE INTERNATIONAL CO-OPERATION

While international co-operation does occur in areas of interest to research reactors, issues requiring attention include the development of low enriched fuel, the exchange of information on operating experience and accidents, the preparation of standards and guides, peer reviews and the regional use of reactors. The development of a protocol for research reactors similar to the Convention on Nuclear Safety, as well as of other arrangements, is being widely discussed at present.

3.5.1. Inadequate use of new fuel development

The development and use of new low enriched uranium (LEU) fuels has been a co-operative effort involving several countries and international organizations, including the IAEA. Silicide LEU fuel has been developed and successfully utilized in many reactors worldwide. However, in order to reach higher density fuels and to solve some issues associated with the back end of the fuel cycle, development of molybdenum–uranium fuels is under way. To achieve widespread use of LEU–molybdenum fuel in research reactors, an international effort for its certification may be required.

3.5.2. Inadequate participation in the exchange of information on research reactors

There is free and open exchange of research reactor technology among research reactor operators around the world. These exchanges consist of training courses, fellowships and conferences organized in specific Member States or regions of the world and around single reactor types. Many such forums are conducted by the IAEA.

While these activities are widespread, operators in developing countries often do not take advantage of these exchanges for many reasons. In most developing countries sufficient travel funds are not available. The lack of sufficient staff to permit a person to be away from the facility is another problem. The relevance of the subject matter may be another reason developing countries may not attend; a conference may be discussing facility upgrades and installation of sophisticated experimental equipment and instrumentation when discussion of basic facility maintenance is what would be of most benefit. A solution may be for the IAEA to continue and increase the offering of national and regional workshops tailored to the needs of the nation or region.

National organizations exist for the exchange of information about research reactor incidents. Until recently, there has not been a formal international system of information exchange for research reactors. The establishment of the IRSRR by the IAEA provides the framework for information exchange about incidents. However, while operational, the IRSRR still lacks extensive participation by Member States, who should be encouraged to join; the success of the programme is proportional to participation.

3.5.3. Inadequate regional use of reactors

Regional sharing of research reactors is most cost effective where a small number of users share costly experimental facilities. Shared facilities are less cost effective where a large number of users must frequently travel to share inexpensive facilities.

While the regional use of reactors is already taking place, it will probably become more popular as reactors age and funding for reactors decreases. Operating systems and experimental facilities become obsolete and upgrades of these systems and facilities at all reactors becomes too costly, resulting in financial pressures for the creation of regional centres of excellence.

The number of reactors in extended shutdown should determine whether the use of another reactor in the region is the preferred way to meet the needs of the user community based on safety, economics and efficiency.

3.5.4. Lack of an international convention or arrangement for research reactors

INSAG has suggested the development of an international protocol or some other legal instrument or arrangement to cover the safety of research reactors in a similar way that nuclear power reactors are covered by the Convention on Nuclear Safety. The IAEA General Conference, recognizing the significant benefits as well as the potential adverse impact of such an arrangement, requested the Secretariat to continue exploring options to strengthen international nuclear safety.

4. RECOMMENDATIONS FOR STRATEGIC ACTIONS/PRIORITIES FOR FUTURE WORK

The recommendations for strategic actions are divided into three groups: international arrangement, regulatory supervision and other issues. While the recommendations apply to all research reactors, they address the problems of that subset of facilities described in Section 1 so as to bring them in line with their peer facilities. A general recommendation is addressed both to Member States and the IAEA on the benefits of developing an international arrangement for research reactors. The term ‘Member States’ refers to both the applicable government unit and the research reactor operator. Frequently, the operator is a unit of the Member State government but in other cases the operator may be an independent body.

4.1. INTERNATIONAL ARRANGEMENTS

The General Conference has asked the IAEA Secretariat to take an active role in exploring the possibilities for the development of an international arrangement for the safety of research reactors.

Authorities in Member States should start thinking about the modality, format and features of such an arrangement.

The benefits of such an international arrangement for research reactor safety will depend on the scope, modality, format and features that may be adopted by the participating Member States.

The IAEA Safety Standards should be recognized as a framework for the international arrangement, which should serve to achieve the following objectives:

— Better understanding of the current practices applied by Member States to all stages of the lifetime of a research reactor facility;
— Greater assurance that common practices based on international consensus standards are applied to all research reactor facilities participating in the arrangement;
— Improved information exchange, credibility and openness among Member States participating in the agreement;
— Creation of a forum for discussing specific issues such as ageing, extended shutdown, regional use of research reactors and common solutions to spent fuel disposal;
— Creation of a systematic consensus framework for benchmarking the safety of research reactor programmes in Member States.

4.2. REGULATORY SUPERVISION

The following are proposed recommendations to solve issues related to regulatory supervision.

To Member States:

— Organize group activities (e.g. workshops, training events) on specific regulatory issues or issues related to specific reactor types;
— Share experience through symposia or international organizations of regulators;
— Ensure adequate funding for regulatory activity;
— Endorse IAEA Safety Standards (or the equivalent) if adequate national safety standards are not available.

To the IAEA:

— Improve regulatory personnel competence through group and individual training;
— Expand International Regulatory Review Team (IRRT) services to Member States operating research reactors;

— Provide for an enabling network between research reactor regulators to examine co-operation, mutual assistance, and the sharing of specialists on regional and bilateral bases.

4.3. OTHER ISSUES

The following are proposed recommendations to resolve technical issues:

Ageing facilities

To Member States:

— Share information on the management of ageing from operational and regulatory activities;
— Establish a programme for physical and non-physical ageing, as is discussed extensively in Ref. [11].

To the IAEA:

— Strengthen group activities such as Co-ordinated Research Projects, workshops and seminars dedicated to ageing phenomena;
— Develop further guidance documents on relevant ageing aspects and address ageing issues in any reassessment of safety at research reactor facilities.

Research reactors in extended shutdown

To Member States:

— Share experience with other Member States also having shut down research reactors;
— Provide funds to manage shutdown as well as decommissioning if this option is chosen;
— Perform a feasibility study concerning early restart and begin decommissioning if the feasibility of restart appears remote.

To the IAEA:

— Complete a guidance document on extended shutdown;
— Co-ordinate group activities, meetings and workshops on extended shutdown and decommissioning;

— Advise Member States on keeping an extended shutdown as short as possible because experience shows that skilled personnel will leave the facility and the amount of deterioration is proportional to the shutdown duration.

Operating organization management

To Member States:

— Develop a strategic plan of the expectations of the research reactor and resources required.
— As a provision of research reactor ownership, provide resources (funds and personnel) for operational states or decommissioning.
— Train personnel in specific activities such as maintenance during extended shutdown, periodic reassessment, etc.
— Ensure that peer reviews are conducted.
— Ensure that a QA programme is established and implemented.

To the IAEA:

— Develop training and tutorial material for self-assessment of safety management practices, safety culture, QA and strategic long term planning.
— Develop guidance on emergency planning and emergency procedure preparation and implementation specific for research reactors.
— Expand peer review services.
— Develop guidance material on the preservation of corporate memory.
— Develop short workshops on specific topics such as (1) the development of an affordable, practical, graded QA programme for the small facility operator; (2) safety culture for the uninitiated: how to generate it and recognize it; and (3) retraining made easy.

International co-operation

To Member States:

— Explore options for and desirability of an international nuclear safety arrangement for research reactors;
— Take advantage of INSARR services both by receiving the service and by supplying experts;
— Participate in the IRSRR.

To the IAEA:

- Sponsor and participate in activities related to the safety implications of new fuels developed for research reactors;
- Initiate and organize meetings, workshops and courses on a regional basis and on specific topics to encourage the sharing of experience between groups that face similar problems;
- Expand the number and scope of review services to reactors under agreement;
- Work to strengthen and increase participation in the IRSRR.

5. QUESTIONS TO THE CONFERENCE

(1) What is the most appropriate modality for an international arrangement which will both be effective in increasing the overall safety of research reactors and also will induce maximum participation of Member States worldwide?

(2) What is an effective approach to resolve the issue of research reactors in extended shutdown? How can a quick decision be made by authorities on whether to restart or decommission? If there are regional centres which could be used by several Member States, would this help to improve the situation?

(3) What is the best way of transferring knowledge and know-how from the nuclear power community to the research reactor community, e.g. in the fields of quality assurance, safety culture, etc.?

(4) How can well run research reactors help problem research reactors?

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Guidelines for the Review of Research Reactor Safety, IAEA Services Series No. 1, IAEA, Vienna (1997).
[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Integrated Safety Assessment of Research Reactor Results (in preparation).
[3] Letter from A.J. Baer, Chairman of INSAG, to M. ElBaradei, Director General, IAEA, 24 April 2000.

[4] Resolution of the IAEA General Conference, The Safety of Nuclear Research Reactors, GC(44)/RES/14 (2000).
[5] INTERNATIONAL ATOMIC ENERGY AGENCY, The Safety of Nuclear Installations, Safety Series No. 110, IAEA, Vienna (1993); and Radiation Protection and the Safety of Radiation Sources, Safety Series No. 120, IAEA, Vienna (1996).
[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Code on the Safety of Nuclear Research Reactors: Operation, Safety Series No. 35-S2, IAEA, Vienna (1992).
[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Code on the Safety of Nuclear Research Reactors: Design, Safety Series No. 35-S1, IAEA, Vienna (1992).
[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report, Safety Series No. 35-G1, IAEA, Vienna (1994).
[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety in the Utilization and Modification of Research Reactors, Safety Series No. 35-G2, IAEA, Vienna (1994).
[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning Techniques for Research Reactors, Technical Reports Series No. 373, IAEA, Vienna (1994).
[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Research Reactor Ageing, IAEA-TECDOC-792, Vienna (1995).

Keynote Paper

SAFETY STATUS OF RUSSIAN NUCLEAR RESEARCH FACILITIES

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Abstract

SAFETY STATUS OF RUSSIAN NUCLEAR RESEARCH FACILITIES.

The Federal Nuclear and Radiation Safety Authority of Russia (Gosatomnadzor) regulates safety and conducts inspection activities related to nuclear and radiation safety at nuclear research facilities, including research reactors, and critical and subcritical assemblies. This involves the implementation of three major activities: (1) establishing the laws and safety standards in the field of research reactor nuclear and radiation safety; (2) research reactor licensing; and (3) inspections (or license condition tracking, inspection and application of sanctions). The database on nuclear research facilities has recently been updated to provide the actual status of all facilities. Many facilities have been shut down, temporarily or permanently, awaiting the final decision on their decommissioning. Compared with previous years, the situation has changed. Currently, there are 99 nuclear research facilities in total under the supervision of Gosatomnadzor (compared with 113 in previous years). The process of regulating safety in the Russian Federation is based on a legal framework consisting of nuclear laws and safety standards, as discussed in the paper. Safety assessments are conducted according to the actual hazard that a facility might represent. This is reflected in the Safety Classification of Research Reactors. Finally, a summary of the safety status is given and major problems at current Russian research facilities are outlined.

1. INTRODUCTION

This paper deals with the safety status of Russian nuclear facilities, and will provide details of the wide Russian experience in the field of research reactor safety. The focus will be only on the following major issues of concern:

— The approach to safety regulation adopted in the Russian Federation;
— The basis for the legislative and safety standards used by the regulatory authority and operating organizations;

— An overview of Russian nuclear research facilities, including their number and safety classification;
— Their safety status, including only basic issues of concern such as incidents at research reactors and spent fuel management problems;
— The basic problems currently being faced at research reactors in the Russian Federation and how we are planning to resolve them.

2. APPROACH TO SAFETY REGULATION

The Federal Nuclear and Radiation Safety Authority of Russia (Gosatomnadzor) regulates safety and conducts inspections at nuclear research facilities, including research reactors and critical and subcritical assemblies, all over the country. The regulation of safety is based on three major aspects:

— Development of the basis for legislative and safety standards;
— Licensing;
— Monitoring of the license condition by means of regular inspections, and deciding on sanctions when violations are detected.

3. BASIS FOR LEGISLATIVE AND SAFETY STANDARDS

Regulatory activities in the Russian Federation are based on laws, safety standards and regulations that were put into force during the 1990s. Before that time there was only a system of supervision based on government resolutions. However, since 1995, nuclear and radiation safety regulations have been adopted that follow IAEA recommendations that are accepted worldwide. Now there is a well structured set of legislative and safety regulation documents, starting with the Russian Federation Constitution of 1993, at the top of a ‘safety pyramid’, proceeding through the President’s Orders, government resolutions, nuclear and radiation safety laws and safety standards, and ending with safety regulations and practices.

4. OVERVIEW OF RUSSIAN NUCLEAR RESEARCH FACILITIES

In order to understand the heavy burden on Gosatomnadzor, an overview is necessary of Russian nuclear research facilities. These consisted of 98 facilities as of July 2001. The number of research reactors has been decreasing between 1998 and 2001 and this tendency has continued due to reasons that will be explained later. Of the facilities under supervision, 38 research reactors are the major problem.

Of these, greater attention is currently being paid to the facilities about to be decommissioned.

It should be mentioned here that a unique situation exists in that the owners of these facilities are under different government ministries and executive bodies (e.g. Ministry of Atomic Energy, Ministry of Education, independent operating organizations, Russian Ship Building Company, Ministry of Natural Resources and the Russian Academy of Sciences). The Ministry of Atomic Energy owns half of all research reactors.

Not all of the above mentioned ministries and executive bodies have the same level of financial ability to support the operation of their facilities. This has created problems, and Gosatomnadzor has repeatedly informed the government of the necessity to develop a clear national programme for research reactors. However, this issue has not been decided on yet at higher government level.

5. RESEARCH REACTOR CLASSIFICATION

Since different research reactors pose different levels of hazard, a classification system has been established. This classification is based on the severity of possible accident consequences and is somewhat similar to the research reactor classification systems adopted in other countries (e.g. in the USA). This is not an absolute scheme with clear boundaries and is, to some extent, arbitrary, but it facilitates supervisory activities and conserves resources in terms of the planning of regular inspections, safety reassessment and of emergency planning.

On this basis we can divide all research reactors into three groups, as follows:

— Above 20 MW(th), which potentially could have consequences over the entire International Nuclear Event Scale (INES). These reactors are basically used for testing nuclear power plant components.
— Below 20 to 1 MW(th), for which the accident consequences could be moderate. These reactors are used for R&D, fundamental studies and radioisotope production. This category appears to be of major concern to the IAEA.
— Below 1 MW(th), for which the accident consequences to the public are limited and basically constitute only on-site consequences.

6. SAFETY STATUS

With respect to the actual safety status of research reactors, it is helpful to examine the major incidents that have occurred in previous years. The slight increase in the number of incidents will be explained later in the discussion of the problems being faced with research reactors.

One of the major efforts to enhance research reactor safety focuses on spent fuel and radioactive waste management. Unfortunately, the number of free cells in the spent fuel storage facilities of the main operating organizations has remained at the same level as in previous years. The main problems involved with spent fuel and radioactive waste management can be delineated as follows:

- — Spent fuel transport from some reactors to a reprocessing plant has not been resolved;
- — A large quantity of large dimension radioactive equipment has been collected at the sites;
- — The technology for some spent fuel elements and non-standard equipment reprocessing has not been developed up to now;
- — Liquid radioactive wastes are not solidified due to lack of resources, and have been stored temporarily at some sites.

All these problems are due to the high costs of transport and reprocessing and lack of a centralized government programme for fuel cycle safety at research reactors, as well as different levels of financing by their respective ministries.

7. BASIC PROBLEMS

The second part of this paper is devoted to the basic problems being faced and the plans to resolve them. Most of these problems are similar to those in other countries.

Topical Issue Paper No. 4 is used as the basis for discussion of these problems. They are grouped into three broad categories: (1) organizational; (2) engineering; and (3) safety regulation.

With regard to organizational problems, there are six issues for peer attention:

(1) Absence of a clear Russian Government programme for research reactor utilization and lack of long term planning at most reactors.
(2) Lack of financial support from the Government for fundamental studies.
(3) Low salary level and, as a result, low prestige of nuclear engineering.
(4) Staff ageing and retirement that result in a loss of expertise and corporate memory.
(5) Inadequate quality assurance (QA) programme for operation.
(6) Lack of systematic reassessment of the Safety Analysis Report (SAR) at some big facilities of major concern.

In order to resolve these problems various measures have been undertaken, the basic ones being the following:

— Repeatedly notifying the Government of the urgent need to define a clear place for research reactors in the nuclear industry and in the Russian national economy in general. Unfortunately, no decision has been made up to now.
— Two institutes under the Ministry of Education, each with a pool type research reactor of 2.5 MW(th), are being used to teach students of nuclear physics and nuclear engineering in order to partially slow the inevitable loss of professional staff. Since both institutes invite foreign students and organize R&D contracts with foreign countries, the financial situation is getting better.
— Issue of a special regulation and also a requirement for license conditions for operators to develop a QA programme and conduct a regular SAR reassessment (every five years at least).

With regard to engineering problems, five basic issues are being resolved as follows:

- **Problem 1: Ageing equipment important to safety.** Basically this involves changes in the properties and structural integrity of the reactor internals such as fuel rods, basket, grid and reactor vessel; drive mechanisms of control rods and control cables, instrumentation and control (I&C) components, power supply components and cables, and heat removal system equipment. To resolve this very important problem, Gosatomnadzor issued Regulation No. NH-024-2000, ‘Requirements for Nuclear Facility Life-Time Prolongation’. This document details the requirements in two broad areas in order to ensure the further safe operation of a nuclear facility:
  — *Organizational issues:* to develop an inspection and test programme based on the parameters approved by the design organization (a ‘founder’ of a nuclear facility) and to involve the competent Russian organizations on such specific issues as the study of metal properties, fatigue problems and structural analysis.
  — *Technical issues:* to accomplish the inspection and test programme under the supervision of the competent organizations, define new operational limits and conditions, document the results, write the SAR and submit it to Gosatomnadzor for review and decision making.

- **Problem 2: Lack of spare parts, especially for I&C systems.** In this case we have two ‘levers’ to improve the situation.

  — Licensing conditions require the operator to: (1) have a sufficient number of spare parts for systems important to safety; or (2) shut down the reactor if the lifetime of an important component is over and it is impossible to justify its further safe operation, whether due to the lack of original parts or for other technical reasons. This is basically for Class 1 and 2 facilities for which a failure could result in significant consequences.

— The Russian Nuclear Law requires the operator to set up a special fund for safety, which could be used to resolve the problem mentioned above.

This was the case at some large reactors where the obsolete I&C systems were replaced with state-of-the-art systems.

- **Problem 3: Reactors in extended shutdown status.** This situation could result in the degradation of equipment and staff. We have started thinking about this problem relatively recently and, based on draft IAEA recommendations, we have issued a regulation (also in draft form) with the following requirement: choose between two options, that is (1) return the facility to operation sometime later, or (2) decommission. If option 1 is selected, more license conditions may be imposed in addition to changes in the operational limits and conditions for the definite shutdown period. In this case, returning to operation will need appropriate commissioning, safety review and permission. If option 2 is selected, the reactor will go to decommissioning.

- **Problem 4: Spent fuel transport from temporary storage facilities at major sites.** Very few research reactor spent fuel assemblies have been shipped to the reprocessing plant at Mayak — the only available facility for reprocessing spent fuel from such reactors. Even after shipment to Mayak, they have been stored there without reprocessing. The reason is simple — lack of financial resources for transport and reprocessing. We have been repeatedly informing the Government of this situation, but no decision has been taken till now. The problem is being resolved by the reactor owners on a reactor by reactor basis if some resources become available.

- **Problem 5: Verification and validation of safety codes and models used in producing the SAR.** In the past there was no requirement nor was there a procedure on how to verify and validate safety codes and models for the SAR, and many research reactors were designed and built in the 1960s using codes and models developed by the three main design organizations. Now we require the operator in the updated SAR to present data on the code and model verification and validation status. In order to unify this process, a regulation has been issued on how to write such a report. This document should be submitted to Gosatomnadzor for review and decision making.

- **Problem 6: Safety regulation.** Beginning in 1995, when a new nuclear law was issued, many safety standards were found to be inadequate or obsolete. We have attempted to resolve this problem over the years in different ways, collaborating with the IAEA, the European Union and with other countries in the area of safety standards, regulation and practices. This is a very productive way to improve safety standards and research reactor safety in general.

8. CONCLUSION

In conclusion, using the IAEA's interpretation of research reactor safety in Topical Issue Paper No. 4, and despite the problems delineated above, the safety status of Russian nuclear research facilities can be assessed as being at the "Desired State". This conclusion is based on the well organized operations at major facilities and the strict supervision of Gosatomnadzor. In the latter case this can be explained by Gosatomnadzor having seven regional offices distributed throughout the main nuclear areas, with a special division of resident inspectors at each scientific and research centre that operates nuclear research facilities. These inspectors (our 'eyes and ears') supervise the operation of research reactors, conduct inspections, issue notifications in case of violations and use appropriate sanctions (enforcement). Gosatomnadzor, management, regional supervision by line inspectors plus a focus on operational safety have all combined to give the Russian Federation a generally good safety record.

Keynote Paper

SAFETY ASPECTS OF SHUTTING DOWN AND DECOMMISSIONING THE EWA REACTOR AND OF OPERATING THE MARIA REACTOR

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Abstract

SAFETY ASPECTS OF SHUTTING DOWN AND DECOMMISSIONING THE EWA REACTOR AND OF OPERATING THE MARIA REACTOR.

In the paper the nuclear safety aspects related to two Polish research reactors, EWA and MARIA, are presented. The EWA reactor is in the decommissioning phase and the problems concerning its ageing, shutdown and decommissioning are described. The MARIA research reactor is in operation at 15–20 MW of power. The problems concerned with its modernization and restart after modernization are described. Also, some questions on ensuring the safe operation of this reactor are presented.

1. INTRODUCTION

There are some special periods of time in the operation of a research reactor during which assurance of an appropriate level of nuclear safety is particularly difficult. One of these periods is when the reactor is restarted after modernization, and the second is when the reactor is old.

The problems that have occurred during these two stages are presented in this paper. The decision to shut down and decommission the first Polish research reactor, EWA, will be described. With regard to the second Polish research reactor, MARIA, some special problems related to nuclear safety that occurred after its modernization are detailed.

2. SHUTDOWN AND DECOMMISSIONING OF THE EWA RESEARCH REACTOR

2.1. History of EWA reactor operation

This WWER type reactor of Russian construction was put into operation in 1958. Operation at 2 MW power was conducted principally for radioisotope production and horizontal beam tube utilization. In 1964, the first modernization phase was conducted and the power increased up to 4 MW. In 1967, the second modernization phase was conducted and the power was increased up to 10 MW. The reactor was in operation at this power until February 1995.

2.2. Decision on EWA reactor shutdown

Two principal factors were taken into account when the decision on reactor shutdown was taken:

— The technical state of the reactor,
— The need for operation of two research reactors in Poland.

The EWA reactor was in operation for 37 years, but from 1967 onwards operated at 10 MW power. This means that for 28 years the reactor operated at a power level that was five times greater than when it was constructed. The value of the thermal power was very significant in the technical applications of the reactor.

In estimating the reactor's technical state, a very important factor is the time of construction. As this reactor was constructed in the former Soviet Union in the 1950s, it does not meet the requirements for nuclear installations, especially the requirements for quality assurance. This was confirmed in 1970 by radiographic tests of the welded joints of the main cooling system. The quality of the joints was not up to the specifications foreseen for this type of equipment.

Nevertheless, based on stress analysis of the tubes and welded joints, reactor operation was permitted. After detection of the unsatisfactory quality of welded joints, frequent quality control checks were conducted (radiographic tests were done twice a year). The results of these examinations confirmed the stability of the welded joints.

The second important factor in estimating the reactor's technical state is the condition of the instrumentation and control (I&C) system. In this case the system was based on electronic lamps for which with the availability of spare parts became increasingly difficult to resolve.

At this time the MARIA reactor went into operation after extensive modernization, as a result of which the production of radioisotopes and utilization of horizontal beam tubes became possible at this reactor. However, after assessing the technical condition of the EWA reactor, and determining that there was no need for the operation of two research reactors in Poland, the decision to shut down the EWA reactor was taken.

2.3. Decommissioning of the EWA reactor

After shutdown of the reactor, it was evident that decommissioning should be started as soon as possible for two reasons:

— To minimize the cost of survey of the reactor during extended shutdown,
— To perform the decommissioning before the operating personnel left the reactor.

After deciding that the reactor had to be decommissioned, the following questions required resolution:

(1) What is the scope of the decommissioning work and the choice of strategy?
(2) Who would be able to do this work?
(3) How much would the decommissioning cost?
(4) What would be done with the operating personnel?

(1) What is the scope of the decommissioning work and the choice of strategy?: These would depend on the use of the reactor building and equipment after decommissioning. The initial analyses of the technical possibilities for utilization of the reactor building after decommissioning indicated the following:

— Construction of a spent fuel dry storage facility in the concrete shaft of the reactor block for spent fuel elements from the EWA and MARIA reactors;
— Utilization of the primary cooling system pumping room for construction of wet fuel storage, or for construction of the transit stand for spent fuel in the case of its transportation abroad;
— Utilization of the hot cells for the fuel element enclosure in hermetic capsules for further stocking;
— Utilization of the hot cells for materials testing;
— Utilization of the reactor hall for construction of the stand for medical equipment sterilization.

The scope of reactor decommissioning is also related to utilization of the building and minimization of the cost. Finally, decommissioning involves the following:

— Removal from the reactor of any radioactive and contaminated materials (except any radioactive elements placed in the reactor biological shield);
— Destruction of any conventional systems such as the secondary cooling system, ventilation systems, electrical supply system and dosimetric system.

The following factors have been taken into account in the choice of the strategy for decommissioning:

— The radiological state of the reactor after shutdown;
— The technical state of the nuclear equipment and reactor block;

— The safety and health physics needs;
— The aspects of waste management;
— The capabilities of the experienced personnel and techniques of dismantling, cutting and decontamination;
— The cost estimation and disbursement of funds;
— The future utilization of the reactor building and block.

Finally, it was decided that future utilization of the reactor building would involve construction of a dry storage facility in the reactor shaft for spent fuel from the EWA and MARIA reactors. This required the retention of important parts of the reactor structure and technological connections, such as ducts and channels, since they could be used in the construction of the dry storage.

It was necessary to carry out decommissioning in such a way as to be able to utilize this installation after 40 or 50 years. After removing the nuclear components from the reactor, dosimetric control confirmed that this goal had been achieved.

The decommissioning of the EWA reactor in this manner shows that medium power research reactor decommissioning can be achieved in a manner that is different from what is commonly done in other parts of the world, i.e. carrying out decommissioning in a ‘green way’.

(2) Who would be able to do this work?: In Poland there is no nuclear power plant programme and, as a consequence, there is no Polish external enterprise capable of carrying out the decommissioning of a nuclear reactor. One possibility that was considered was to engage a foreign enterprise. However, for economic reasons this idea was dropped.

Since the decision was taken to carry out the decommissioning by ourselves, this meant engaging EWA operating personnel, Waste Management Service staff, Health Physics Service personnel and so on. This was a difficult decision because we did not have experience in decommissioning. However, EWA reactor personnel had very good knowledge of the technological systems of the reactor and of the principles of working in nuclear installations.

To ensure a safe decommissioning process, it was necessary to:

— Develop a quality assurance programme for decommissioning in which the role and responsibilities of everyone involved were described,
— Develop a set of technological and operational procedures,
— Organize training for personnel involved in decommissioning tasks.

In this regard, training was focused on:

— Technological and operational procedures,
— The special equipment used in the dismantling work,

— The radiological aspects of the tasks,
— Actions to be taken in emergency situations.

The responsibilities of the principal departments of the Institute of Atomic Energy in the decommissioning of the EWA reactor were as follows:

(a) EWA Reactor Operation Department:
— Preparation of documentation for decommissioning (plan for the decommissioning, the quality assurance programme for dismantling tasks, procedures for dismantling, etc.);
— Organization and training of personnel participating in dismantling tasks;
— Survey of dismantling tasks;
— Collection of documentation;
— Carrying out of chemical analysis;
— Survey of the reactor;
— Preparation of the final report.

(b) Reactor Analysis and Measurement Department:
— Calculation of the activity of the reactor elements;
— Spectrometric analysis confirming the calculation of the reactor element activity;
— Control measurement during dismantling.

(c) Reactor Engineering Department:
— Elaboration of projects and manufacture of the special equipment for dismantling;
— Direct participation in the dismantling operation;
— Approval of materials and equipment.

(d) Dismantling groups:
— Specification of the dismantling tasks based on approved procedures,
— Decontamination tasks,
— Segregation of wastes and their packaging.

(3) How much would the decommissioning cost? The total cost of decommissioning the EWA reactor is $1.1 million. We have received $200 000 in financial support from the IAEA, which was used for equipment purchase and missions of international experts. The sum of $900 000 was donated by the Polish National Atomic Agency.

(4) What would be done with the operating personnel? There were 46 persons who were engaged in reactor operation by the time the reactor was shut down in 1995. Of these, a large part was at retirement age: 21 persons have retired. Five persons were transferred to the MARIA Reactor Operation Department and 20 persons have been engaged in decommissioning work for the reactor.

3. RESTART OF THE MARIA REACTOR AFTER MODERNIZATION

3.1. History of operation of the MARIA reactor

The MARIA reactor achieved first criticality in 1975 and was operated until 1985 at 20–25 MW for radioisotope production and beam tube and experimental rig utilization. As the nuclear power programme was developed in Poland, a high pressure test facility for the MARIA reactor was constructed. In 1985, modernization of the reactor was initiated in parallel with the installation of a high pressure loop in the reactor. After modernization was completed in 1992, the reactor was restarted. Unfortunately, at this time, the decision on stopping construction of the first Polish nuclear power plant was taken. As a result, the operation of the high pressure test facility was halted and operation of the MARIA reactor for rig and loop utilization was also stopped. The decision was taken to restart the reactor for radioisotope production and horizontal beam tube utilization.

3.2. Taking the decision on reactor modernization

In many countries the safety of nuclear installations is influenced by the political and economic situation. The Chernobyl accident is one example. At the time of startup of the MARIA reactor in 1975, the political situation in Poland was not conducive to the assurance of nuclear safety. The reactor startup time was defined and it was very difficult for those responsible to change this time. The result was that the reactor was put into operation in an unsatisfactory technical state, without complying with nuclear safety rules. In consequence, it was only after ten years of operation that the decision was taken on reactor modernization, mainly to ensure nuclear safety and also to improve disposability.

3.3. Safety aspects in the process of restarting the MARIA reactor after modernization

Modernization of the MARIA reactor was carried out from 1985 to 1991. This was a very long time, too long for modernization. Why did it take so long? Some reasons were:

— Lack of money for modernization,
— Installation of a high pressure test facility in the reactor,
— Problems with the regulatory body after the first edition of the Polish Atomic Law was issued.

In 1986, the Atomic Law was revised, focusing particularly on issues related to the construction of nuclear power plants. The application of some articles to research reactors was not clear. Their different interpretation by the regulatory body and operators was a source of long discussion and, consequently, loss of time. As a result, it was necessary to:

— Prepare a new Safety Analysis Report,
— Develop a quality assurance programme for operation,
— Develop a training programme,
— Carry out the process of requalification of the operating personnel,
— Carry out a psycho-physical examination,
— Carry out appropriate training after the licensing of personnel.

Very often the modernization of a reactor is the occasion to perform a general, detailed reassessment of reactor safety. This was also true in our case. At the time of modernization the first general reassessment of the MARIA reactor's safety was carried out.

After the modernization programme, the reactor was in a very similar state to first startup. The process of testing, verification and analysis foreseen in the quality assurance programme was very extensive and complicated. Also, development of the Safety Analysis Report required a lot of work. Many calculations and analyses demanded by the regulatory body had to be carried out.

An overly long modernization process has a very bad influence on the morale of reactor personnel, particularly if this process is extended several times. People become tired by the lack of clarity of the situation. In our case this was especially important because the reactor operators were not very busy during the modernization process. In these circumstances, the process of operator requalification is very important and should be carried out with the highest priority. After six years of interruption in their normal duties, it was evident that retraining should contain lectures as well as practical training.

The lectures concentrated on safety aspects and a detailed presentation of the modifications that had been carried out. The second part of retraining was practical training carried out on the AGATA critical assembly. This is a small scale copy of the MARIA reactor, built during the construction of MARIA, for determination of the principal nuclear characteristics of this type of reactor. Afterwards, AGATA was used mainly for training. Thus, it was very good for carrying out the practical retraining of MARIA reactor operators. Another part of the practical training was the set of computer exercises prepared for important reactor physics phenomena such as xenon poisoning and balance of reactivity. After retraining, the licensing process was carried out.

3.4. Current training and qualification of MARIA reactor operating personnel

A very important factor in ensuring the safe operation of a reactor is maintaining a high level of safety culture. Personnel should be very knowledgeable, well trained and engaged in applying safety culture at the reactor. To guarantee a high level of safety culture, an appropriate system of training and qualification of reactor staff has to be applied.

Licensing: According to the Polish Radiation Protection Law, every member of the reactor staff has to have a specific licence. There are two types of licences:

— Issued by the President of the National Atomic Agency,
— Issued by the Director of the Institute of Atomic Energy (the owner of a reactor).

The first is for staff working in posts that have the principal responsibility for guaranteeing the safe operation of the reactor: the reactor manager, shift supervisor, reactor operator and senior health physicist. The second type is for the health physicist, mechanic, electrician and instrumentation and control (I&C) operator. To be relicensed, every staff member has to undergo a re-examination on a periodic basis of his or her medical and psychological state and has to pass a re-examination of his or her knowledge. This is done at the following intervals:

— Five years: reactor manager.
— Three years: shift supervisor, senior health physicist.
— Two years: reactor operator, health physicist, mechanic, electrician and I&C operator.

Training: Each candidate for the staff has to have an adequate background and pass complex training in the field of nuclear physics, reactor physics, radiological protection, reactor construction and systems, the Safety Analysis Report and the quality assurance programme. This training is carried out through a system of lectures, practical training and self-study.

Retraining: This is a very important item which guarantees that the knowledge of the staff is appropriate and current. Retraining is carried out through a system of lectures and seminars on the following subjects:

— Nuclear and radiation safety,
— Lessons learned from reactor accidents and incidents,
— Discussion of the reactor’s unplanned shutdowns, and malfunctioning of systems and components,

— Discussion of reactor modifications and their influence on safety,
— Emergency preparedness and drills.

It is important in this retraining that the members of the Nuclear Safety Committee (NSC) participate. The members of the NSC are the best specialists in nuclear fields.

4. CONCLUSIONS

To ensure the safe and economic decommissioning of research reactors, it is important to carry out the process as soon as possible after shutdown, and before the operating personnel leave the reactor. Modernization of a research reactor can be complicated, and the restart process after modernization can be difficult and long drawn out. To minimize problems, it is recommended that a detailed plan be prepared for modernization, with precise assessment of the costs. Sufficient funds must also be available.

Lead-in Discussion

INTERNATIONAL ARRANGEMENTS FOR INCREASING THE SAFETY OF RESEARCH REACTORS

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1. INTRODUCTION

In 59 years of operating experience with research reactors, no accident has occurred that has led to an off-site impact. This record represents one of the proofs that research reactors are still quite safe, regardless of their age.

However, Topical Issue Paper No. 4, Safety of Research Reactors, in particular paragraph 1 in the section entitled ‘Rationale’, signals to the nuclear community that action must be taken with respect to the safety of research reactors. In fact, the IAEA has developed and offers various programmes to assist Member States in increasing the safety of research reactors, such as the INSARR (Integrated Safety Assessment of Research Reactors) and IRRT (International Regulatory Review Team) programmes; recently, the IRSRR (Incident Reporting System for Research Reactors) has been placed in full operation. And yet an INSAG (International Nuclear Safety Advisory Group) report alarms the nuclear community with the following statements: “In spite of the prompt reaction of the Secretariat, …the problem remains **very serious**…” The INSAG report further states that “…INSAG considers that adding a Protocol to the Convention on Nuclear Safety to cover research reactors would be a major contribution towards a better, international safety framework for these reactors”. Further, the 2000 IAEA General Conference passed Resolution GC(44)/RES/14 which, inter alia, “calls upon all Member States with research reactors to ensure that those reactors are subjected to strict safety and radiation protection arrangement”.

The question before us here is: What is the most appropriate modality for an international arrangement which will be effective in increasing the overall safety of research reactors and will also induce maximum participation by Member States worldwide?

2. DISCUSSION

Some options can be discussed and elaborated here. Firstly, there is the **INSARR** programme of the IAEA. This is a good programme, assisting Member States to improve the safety of research reactors. The programme is already available, funds are secured, inter alia, through the IAEA's technical co-operation programme, and the international community can participate by providing experts invited by the IAEA. The INSARR programme can be implemented at any time, but unfortunately needs to be requested by Member States. In this sense it is quite different from the IAEA's safeguards inspections. The IAEA can send its safeguards inspectors at any time according to its time schedule as it is a mandatory duty of the organization.

The outcome of INSARR missions is recommendations to the requesting Member State. The State concerned can either follow up and implement the recommendations, or take note of them with no further action. There is no mechanism to ensure that INSARR recommendations are being followed up and implemented.

The situation might be different if a country with a research reactor has established an independent regulatory body. The regulatory body could submit a request to have an INSARR mission carried out, and demand that the operator follow up and implement the INSARR recommendations under penalty of suspending the operator's license.

The conclusion of the above discussion is that 'a country with research reactors has to establish an independent regulatory body'. If this is the case, it would be in harmony with the INSAG proposal to add a protocol to the Convention on Nuclear Safety to cover research reactors that would be comparable to the protocol that has been added to safeguards agreements.

Article 8 of the Convention on Nuclear Safety stipulates that "each Contracting Party shall establish or designate a regulatory body entrusted with the legislative and regulatory framework …", and "each Contracting Party shall take the appropriate steps to ensure an effective separation between the function of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy".

Such an arrangement might be effective in improving the overall safety of research reactors and is less costly. However, it is possible that Member States may or may not join the Convention and its protocol. It is entirely up to them, as it is their sovereign right. Further, the Convention and its 'additional protocol' will be in force only after it has been ratified by the Member States concerned. Although the arrangement is rather passive, it is more common and could be acceptable to most of the IAEA's Member States.

Another, rather active, arrangement is the establishment of an International Working Committee on Research Reactor Safety. The members of this Committee should be selected from among Member States with research reactors. The regional grouping of the IAEA's membership would be similar to that on its Board of Governors (Article VI of the IAEA Statute). Each regional group would select two countries with research reactors as their representatives to serve on the Committee, and each country would send two senior representatives, one from the regulatory body and the other from the operating organization. To increase the involvement of Member States, membership on the Committee would be for two years only and members would be replaced by two other countries from the same regional group. The IAEA would act as the Secretariat of the Committee.

The Committee would be endorsed by the Board of Governors, or even approved by the General Conference, as one of its vehicles to increase the safety of research reactors worldwide. The recommendations of the Committee on the safety of research reactors would be binding, and Member States would be obliged to take action to implement the recommendations. The involvement of Member States, as represented by their regulatory body and their research reactor operators, would be one important element of the Committee in obtaining the commitment of Member States to increasing the safety of their research reactors. The Committee would have to work out in detail the terms of reference for its tasks, which would include:

— the possibility of recommending INSARR missions to Member States;
— endorsing INSARR recommendations, which will be implemented by the Member State concerned; and
— proposing, whenever necessary, the establishment of a regional arrangement for the development of joint programmes to share experiences by conducting joint research, joint on the job training, joint workshops and other activities in the area of research reactor safety and utilization.

What remains to be determined in this exercise is the financial structure that would support this Committee.

Lead-in Discussion

EXTENDED SHUTDOWN, RESTART AND DECOMMISSIONING OF RESEARCH REACTORS

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The focus of this lead-in discussion is on the following questions:

— What is an effective approach to resolve the issue of research reactors in extended shutdown?
— How can a quick decision be made by the authorities on whether to restart or decommission research reactors?

All of us present here will agree that extended shutdown is the most undesired mode for a research reactor. If that is the case, then why are governments and operating organizations keeping research reactors in extended shutdown, and why are regulators acquiescing to this? In my opinion, this is because governments, operating organizations and regulators have different views on this issue, based on their respective interests. Governments would like to keep research reactors (operating or in extended shutdown mode) because they have made an investment in establishing the facilities and their public sees such reactors as a symbol of progress and national prestige. Decommissioning them may create a great deal of controversy and make it difficult for them to convince the public of the need for such decommissioning. For operating organizations, research reactors (operating or in extended shutdown mode) could be a source of income; there may also be research institutions or training facilities built around the research reactor that provide employment to highly educated and trained personnel. Operating organizations will, therefore, try to delay decommissioning and keep the research reactor in the extended shutdown mode for as long as possible. In some developing countries, where the issue of extended shutdown is more prominent, there may be no regulatory authority at all, or the regulator might not have the required authority to declare a research reactor to be unsafe, thereby recommending that it be decommissioned.

What should be our approach to resolve this issue? That is, to restart, decommission or do something else? There are 258 research reactors in the world in extended shutdown mode. Most of them cannot be decommissioned or restarted without a feasibility study. The bases of this evaluation should include the concerns of all parties mentioned earlier. All affected Member States should accept the conclusion of this evaluation, as this would be in the interest of the safe operation of research reactors. On the basis of this evaluation, Member States decide to restart or decommission their research reactors. However, such an evaluation of these 258 reactors will take a lot of time and money. We are aware that the extended shutdown status of several research reactors may be far from satisfactory. These are a potential risk to the safety of operators and the public, the environment and the nuclear industry as a whole if they are hastily restarted or remain in extended shutdown mode. This is because the negative consequences of an accident in a research reactor would not remain confined to such reactors only; they would affect the nuclear power industry and the facilities upstream and downstream. This situation warrants urgent interim action to at least reduce, if not eliminate, the risk. One approach for the resolution of the issue of extended shutdown is to make every effort to keep the reactor in this mode as orderly and for as short a time as possible. I prefer to call such an extended shutdown an ‘orderly extended shutdown’. In such a mode, procedures/measures approved by the regulator are in place to maintain the modified operational/surveillance limits during the extended shutdown, and expertise and funds are available to keep research reactors in this mode according to operating policy, safety commitments and license conditions.

Of the 258 research reactors, only those reactors would qualify for orderly extended shutdown that have:

- structures, systems and components with significant useful life remaining;
- a meaningful utilization programme after recovery from extended shutdown;
- a valid siting and design safety case;
- undergone periodic safety reviews carried out before and during extended shutdown, and the regulator agrees to the resumption of normal operation after termination of extended shutdown.

Those research reactors that cannot be placed in orderly extended shutdown should be candidates for decommissioning. For this to happen the consent of the Member State owning such reactors (and with less developed nuclear programmes) is a prerequisite. To obtain this consent, the concerns of such States would have to be allayed jointly by the IAEA and other Member States with developed nuclear programmes, mainly by presenting acceptable alternatives. For instance, such Member States need to be assured that if in the future they need training facilities, want to perform research or produce radioactive isotopes requiring irradiation, the necessary assistance will be available to them. Assistance with decommissioning should also be readily available to Member States, on request. This may be an effective approach to resolve the issue of research reactors in extended shutdown mode.

Regarding the bases for a quick decision to restart or decommission, in my opinion and experience, the overriding consideration for the authorities should be verification that the safety case presented at the time of licensing is still valid. My experience is that this would involve verifying that the current demographic patterns around the research reactor are as predicted in the Final Safety Analysis Report (FSAR), and design factors such as seismic inputs, flooding levels, etc., are still valid. In case these have adversely changed, the revised safety case based on the current information should be reviewed and accepted by the regulator. In addition, it should be confirmed that plant equipment has not degraded the level of redundancy, diversity and reliability provided in the design, or that corrosion has exceeded the design limits. Furthermore, it should be checked that the engineered safety features have been verified to be capable of performing their intended design functions. The availability of trained and qualified operators and emergency plans adds to the margin between known unsafe and known safe conditions. If such a margin is large, a decision to restart can be made quickly. It is the practice in Pakistan to verify that each barrier between known safe and known unsafe conditions is maintained, and that these add up to a large margin. Figure 1 further clarifies this approach.

In the 21st century, no matter how safely a research reactor is operated, the public will accept it only when there is visible, strong and independent regulatory oversight. Therefore, the decision to restart should be permitted for those research reactors that have been under regulatory review throughout their life, and continued operation is recommended by periodic regulatory/peer reviews and self-assessments.

Another issue is the continued utilization and, consequently, the assured funding of future research reactor operation. In my opinion, reactors that receive funding but are not utilized may not be in a safe state. Consequently, there will be degradation in work practices, leading to an unsafe state. Such reactors should be decommissioned, especially if the Member State has more than one research reactor, and no nuclear power plant.

Another basis for making a decision to restart or decommission is the condition in which the research reactor was maintained during extended shutdown. If proper procedures/measures were not implemented, then an assessment of the reactor's condition is necessary. This assessment may be expensive, and its findings are usually qualitative and inconclusive. A decision to restart may be impeded, further prolonging the extended shutdown period, leading to early decommissioning.

Governments and operating organizations may be hesitant to proceed with decommissioning owing to lack of expertise or infrastructure. They may lack long term, high level radioactive storage facilities, remote handling tools, etc. The IAEA, other agencies and Member States can provide and/or share these and similar facilities with the requesting State.

The IAEA and Member States with developed nuclear programmes can also help other States in making quick decisions. Although the decision to restart or

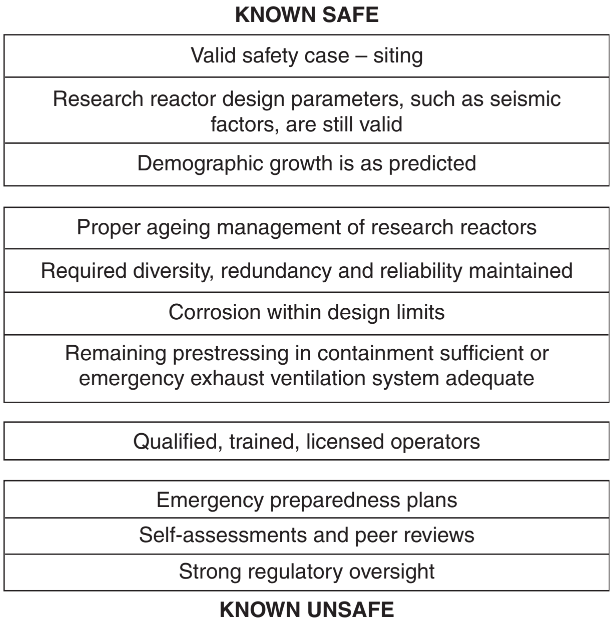

FIG. 1. The greater is the gap between known safe and known unsafe conditions, the stronger is the safety case for research reactor restart.

decommission a research reactor rests with the individual Member State, the IAEA and other States can provide all possible assistance, if requested. A State with research reactors in extended shutdown mode can take quick decisions during the decision making process to restart or decommission by adopting the criteria/procedures followed in model research reactors. Documentation incorporating such experience should be prepared and widely disseminated. Personnel from Member States with reactors in extended shutdown should be provided with opportunities to share such experience with model research reactor facilities.

Lead-in Discussion

TRANSFERRING KNOWLEDGE AND KNOW-HOW FROM THE NUCLEAR POWER COMMUNITY TO THE RESEARCH REACTOR COMMUNITY

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Question 3 from Topical Issue Paper No. 4: What is the best way of transferring knowledge and know-how from the nuclear power community to the research reactor community, e.g. in the fields of quality assurance, safety culture, etc.?

To answer the question on how to transfer knowledge and know-how from the nuclear power community to the research reactor community, one should first try to establish what are the differences and similarities between these types of nuclear facilities.

Despite the big difference between the primary objectives of these two kinds of facilities, i.e. electricity production versus providing irradiation services, the underlying safety culture should be comparable. Both organizations must justify their existence to society at large. While nuclear power plants are characterized by a business oriented organization, most research reactors are still characterized by a professionally inclined organization in which a balance has to be found between scientific, research and development and commercial irradiation services.

For historical reasons, nuclear power plant management took the lead in establishing fully accepted safety standards. However, research reactors can avail themselves of the wide body of nuclear safety experience accumulated at nuclear power plants. This information can be obtained:

— Through open on-site and off-site communication;
— Through training for all staff in the areas of nuclear safety and emergency preparedness;
— Through long term maintenance planning;
— Through audits and plant walkdowns by nuclear power plant staff at research reactor facilities using the applicable requirements of the World Association of Nuclear Operators.

— Through the establishment of a Quality Working Group in which both nuclear power plant and research reactor organizations participate;
— Through the adoption of a common attitude towards nuclear regulatory supervision;
— By collaborating as nuclear colleagues, i.e. without preconceived notions of hierarchy;
— By applying nuclear power plant requirements as far as reasonably practicable;
— By considering quality assurance as a management tool for continuous improvement, rather than a management target.

The above should be applicable to all nuclear facilities. Nonetheless, in transferring their know-how, safety specialists should take into account the huge differences between critical assemblies, university reactors, small research reactors and multi-purpose high power research reactors. The goal to which a specific facility is dedicated bears heavily upon the outlook of its management

Question 4 from Topical Issue Paper No. 4: How can well run research reactors help problem research reactors?

To answer this, a basic question should in turn be posed: Should one help a research reactor with operational difficulties? And, if so, to what extent? Who will benefit? Within the framework of this meeting, one should concentrate on nuclear safety, which is determined by:

— Safety culture (including quality assurance);
— The level of training of all staff;
— Ageing (installation, staff and documentation);
— The front/back end of the fuel cycle;
— A strong programme versus extended shutdown;
— Regulatory (nuclear regulatory) inspectorates;
— National (international) co-operation;
— The financial situation prevailing at the installation.

The satisfaction by each research reactor of these previously agreed indicators (or conversely, its failure to satisfy them) will determine the status of that reactor. When a minimum value of a predetermined scale cannot be achieved by a specific facility, general justification for continued operation does not exist. Instead of assisting these reactors, the recommendation should rather be to shut them down and eventually decommission them, as applicable.

If a minimum performance indicator is met, well operated facilities can help by means of:

— Exchanges of staff and training programmes,
— Plant walkdowns,
— Co-operation on mutual programme definitions,
— Backup scenarios for commercial utilization.

In this process of transfer of know-how, one should keep in mind that the improvement of nuclear and operational safety (including their radiation protection and health physics aspects) should have highest priority. Furthermore, commercial constraints might seriously jeopardize the exchange of information and level of openness during discussions.

Topical Issue No. 5

SAFETY PERFORMANCE INDICATORS

(Session 5)

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Topical Issue Paper No. 5

SAFETY PERFORMANCE INDICATORS

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1. RATIONALE

1.1. BACKGROUND

Since its creation the nuclear industry has been struggling with the question of how safe is safe enough. Safety is a goal common to all involved in the design, operation and regulation of a nuclear installation. As a concept, safety is not easy to define. However, there is a general understanding of what attributes a nuclear power plant should have in order to operate safely. The challenge lies in measuring the attributes.

The new competitive, open, electricity market in many countries throughout the world is increasing the economic pressure on operators to lower operating costs without jeopardizing safety. There is also a driving force to let regulations and regulatory decisions be influenced by risk insights and licensee performance to sharpen the safety focus on the real safety issues.

Challenges are occurring at a rate that is unprecedented in the nuclear industry. Competitiveness; downsizing; ageing; policy changes; reorganization; restructuring; mergers; globalization; and takeovers demand increasing attention to the management of safety.

If safety is not easy to define, it is even more difficult to define and assess a high level of safety. A high level of safety is the result of the complex interaction of engineered safety and operational safety. Experience has shown that focusing on any single aspect of performance is ineffective, and can be misleading. What is more valid is the broader picture presented by a set of indicators designed to monitor key aspects of operational safety performance.

There are various means to measure safety performance, some of which are more qualitative in nature, and others which, through quantitative measures, provide the means to evaluate performance trends with clear ties to safety.

According to their use, indicators are generally considered in two groups: leading or proactive and lagging or reactive indicators. Leading indicators are most useful as a precursor to safety degradation for early management reaction. Lagging indicators are most commonly used to drive plant performance, to monitor, and for benchmarking against similar plants.

The actual values of the indicators are not intended to be direct measures of safety, although safety performance can be inferred from the results achieved. The numerical value of any individual indicator may be of no significance if treated in an isolated manner, but can be made significant when considered in the context of the performance of other indicators.

On the other hand, specific indicator trends over a period of time can provide an early warning to plant management to investigate the causes behind the observed changes. In addition to monitoring the changes and trends, it may also be necessary to compare the indicators against identified targets and goals to evaluate performance strengths and weaknesses.

Each plant needs to determine which indicators best serve its needs. Selected indicators should not be static, but should be adapted to the conditions and performance of the plant, considering the cost or benefit of maintaining each individual indicator.

The operating experience over the past thirty years has led the industry to understand that plants with excellent safety records also tend to be good performers. Therefore, a complete set of parameters to monitor nuclear power plant performance should include both safety and economic performance indicators. Safety and reliable operational performance are not mutually exclusive.

It should be recognized that while indicators provide valuable information in the effective management of plant safety performance, they are just one of a larger set of tools including probabilistic safety assessment (PSA), regulatory inspection, quality assurance, external reviews and self-assessment needed to assess operational safety performance. The integration of information compiled from such evaluation tools yields the best results.

Two areas of increasingly common interest are ‘risk based’ indicators, and ‘safety culture’ indicators.

Industrial experience and research findings have shown that major concerns regarding the safety of nuclear power plants and other complex industrial systems are not so much about the breakdown of hardware components or isolated operator errors. Most important are the insidious and accumulated failures occurring within the organization and management domains. Common to many plants that have had to be shut down because of safety problems has been the fact that senior utility management failed to recognize, within the suite of the performance indicators used, the symptoms and significance of shortcomings and progressive degradation in the safety management processes and safety culture, and hence failed to take corrective action at an early stage. In their early operation many of these plants belonged in the league of best performing plants as measured by the means available at the time.

The key to managing the nuclear business today is to establish a high quality safety management system, as well as developing a strong safety culture within the entire organization. Such organizations will also be committed to continuous improvement and have an integrated set of performance measures and programmes created to act upon that information at all levels of the organization. Included in these measures are indicators that allow for early detection of failures in the management of safety and safety culture.

“The safety management system comprises those arrangements made by the organization for the management of safety in order to promote a strong safety culture and achieve good safety performance” [1]. This definition, presented in INSAG-13, illustrates the close connection between “safety management systems” and “safety

culture" and that they are in fact inseparable. To manage safety effectively you need a systematic approach and at the same time be aware of the effects of the approach on individual and collective human behaviour.

The risk based indicator system is another safety information tool. Generally, this tool can be used to monitor safety performance, both during nuclear power plant operation and shutdown modes, and to alert the user if parameters exceed certain levels or follow undesired trends. Different kinds of information can be derived from the PSA as indicators for long term or short term applications. The long term risk based indicators focus on monitoring plant behaviour in order to obtain insights on the past history of nuclear power plant safety and to update the calculated average core damage frequency. Risk based indicators for short term use require instantaneous evaluation of risk.

1.2. DEVELOPMENT OF SAFETY PERFORMANCE INDICATORS

After accumulating more than forty years of experience, through learning and safety backfitting, the nuclear industry and regulators are ready to use that operating experience and risk analysis to focus on the most significant aspects of plant safety.

Nuclear power plants are developing human performance, self-assessment and corrective action programmes to improve safety and production. Operating experience is shared throughout the nuclear industry and incorporated into these programmes. Probabilistic safety assessment techniques have also improved and expanded so that risk insights are being increasingly used.

In the regulatory field there is a clear tendency to combine the traditional deterministic and the risk informed, performance based ways of looking at what is important to ensure public health and safety.

Risk informed, performance based regulation needs a comprehensive set of safety indicators as an important oversight tool. At the same time it is necessary to preserve the current regulatory requirements and criteria especially in safety areas, which are not covered by the set of indicators.

A new approach should be designed to fulfill the needs of nuclear power plants while maintaining an effective regulatory oversight programme.

1.2.1. Objectives of safety performance indicators

The following objectives are suggested:

— Provide an objective measure of the safety performance of nuclear power plants with regard to public health and safety. It can be combined with other inputs such as inspections, evaluation of findings and audits to assess more completely plant safety performance. The way such insights are combined depends on the purpose of each particular use.

— Provide understandable safety performance information to technical and non-technical persons.
— Provide indicators to assess behaviour and trends in key areas of safety performance so as to allocate resources in an effective and efficient manner.
— Facilitate communication between regulators and licensees. In combination with other information, this enables indication of early signs of degradation.
— Facilitate efforts of licensees to improve their safety performance through an appropriate national and international comparisons, and inform the public of nuclear power plant safety. Safety performance should be measurable and quantifiable to the maximum possible extent.

1.2.2. Benefits of safety performance indicators

The potential benefits of such a comprehensive set of safety performance indicators (PIs) are as follows:

— Identify an objective, auditable and non-disputable set of safety parameters;
— Provide insights, when used as a set, regarding what is important to safety;
— Provide information that is understandable to all stakeholders;
— Provide an additional basis for self-assessment and for taking corrective actions;
— Provide an additional basis for investigations by regulators;
— Enable comparisons to be made, especially in the framework of a small set of internationally agreed safety indicators;
— Encourage licensees to monitor performance using specific indicators;
— Promote the licensees' own improvement of processes.

1.2.3. Precautions in using safety indicators

The following warnings apply:

— Indicators cannot be used alone to draw conclusions for one safety performance area;
— Some indicators are difficult to define without ambiguity;
— Results may be misleading if seen as a measurement of safety level instead of an indication of a particular aspect of an area of performance;
— Indicators can be subject to misuse or manipulation;
— When using composite indicators, a good trend in one specific indicator can mask a bad trend in another;

- An indicator trend is not necessarily indicative of the trend in safety performance;
- Data collected by plant personnel must be verified to ensure their accuracy;
- Lagging indicators may not provide timely indication of declining performance;
- Some safety PIs can only be effectively used as part of a full set of indicators that provide information regarding a spectrum of safety attributes;
- It is difficult to develop quantifiable indicators for some safety performance areas;
- When indicators are plant specific they are not appropriate for comparing plants, particularly if the definition and criteria are different from plant to plant and country to country;
- Indicators cannot replace qualitative engineering judgement.

1.3. INDICATOR SELECTION AND USE

The development of traditional nuclear safety indicators has been concentrated on two major parameters: event occurrences and safety system performance. There are clear limitations in this set of indicators. In the case of event occurrences the limitations are lagging indicators and thresholds that are often too high to allow for early problem identification and intervention. In the case of safety system performance, they are geared towards operating systems, focused on hardware. However, a decline in safety system performance can be an indication of poor human performance in maintenance and operation. On the other hand, good equipment performance may contribute to organizational complacency.

Managing safety performance requires identification of declining trends at incipient stages. Nuclear power plant indicators need to broadly address technical and organizational issues, be sensitive to the kind of issues important for the plant and have thresholds low enough to allow for early identification of problems and rapid intervention.

Key safety PIs should provide the earliest possible warning that an organization has declining performance and this could be increasing the operational risk. It is therefore essential to use a broad set of key indicators to cover the plant's general performance: nuclear safety, environmental safety, industrial safety, and aspects of safety culture and management.

The selection and use of PIs require previous consideration of specific criteria and characteristics for their effective use to monitor operational safety performance, among which are the following:

- There is a direct relationship between the indicator and safety,
- The necessary data are available or capable of being generated,

— The indicators can be expressed in quantitative terms,
— The indicators are unambiguous,
— Their significance is understood,
— They are not susceptible to manipulation,
— They are a manageable set,
— They are meaningful,
— They can be integrated into normal operational activities,
— They can be validated,
— They can be linked to the cause of a malfunction,
— The accuracy of the data at each level can be subjected to quality control and verification,
— Local actions can be taken on the basis of indicators.

Criteria should be used by management to alert them to indicators containing subjective input or that are subject to manipulations, so that abuses do not occur.

2. STATUS OF THE TOPICAL ISSUE

There are two main driving forces to use safety PIs. The first requires nuclear power plants to collect data and process a set of indicators prescribed by the regulatory body, or recommended by national or international organizations. The second is a voluntary approach which depends on individual initiatives of nuclear power plants for internal use or for comparisons with the international situation.

2.1. ISSUES ON WHICH THERE IS GENERAL AGREEMENT

It is generally agreed that a comprehensive set of safety PIs must be used in combination with other insights such as safety culture and human performance evaluations, inspections and audits, risk analysis, feedback of experience and other external review and self-assessment tools in order to have a complete safety management system.

In an increasingly competitive environment both an international set of a few principal performance indicators and a plant specific set of safety PIs can be valuable tools to enhance performance. They provide a standard to strive for, help determine what requires attention, and maintain or even improve the level of quality and safety, thereby avoiding complacency.

Safety indicators have always been used informally by regulators to trigger investigations or initiate regulatory actions. There is a recognized need to consider the licensee's performance in the regulatory decision making process because of the current challenges facing the operating organizations and the nuclear industry. Safety performance indicators are one of the available tools.

2.2. PRESCRIBED OR RECOMMENDED INDICATORS

2.2.1. Safety PIs prescribed by national regulatory bodies

Safety PIs are used to guide regulatory activities and to identify the need for changes in regulatory inspections, and other regulatory actions based on the safety performance of the licensee.

A good example is the approach of the US Nuclear Regulatory Commission (NRC). The NRC has recently announced the 'New NRC Reactor Inspection and Oversight Program', introducing a new approach to the regulation of the nuclear industry. This approach is the risk informed, performance based approach to regulation that has been discussed in several forums over the past years. One key area in this approach is the regular measurement of the safety performance of nuclear power plants; the consequent regulatory actions are based on the actual safety performance. The basis for monitoring the safety performance was the identification of "cornerstones" of safe nuclear plant operation, being characterized by a set of safety PIs. Each PI is categorized to determine the appropriate regulatory response. The PIs are monitored by NRC staff and reported quarterly by the utilities, and they are also publicly available .

The new indicators used by the NRC for regulatory oversight are defined in considerable detail in a Nuclear Energy Institute (NEI) publication (NEI 99-02) [2] and on the NRC web site at *http://www.nrc.gov/OPA/assessment.htm.* Two points about the NRC programme must be emphasized. First, it is in its infancy. The definitions for some of the indicators are undergoing revision and pilot testing based on early recognition that some of the first indicators as described in NEI 99-02 could have unintended consequences.

The second point is that the indicators themselves tend to define operating "safety" parameters, but they do not of themselves describe risk. The connection to risk is achieved through the establishment of threshold levels. Understanding this leads to the concept of performance bands.

The practices in several countries is to use a set of safety indicators, mostly the indicators of the World Association of Nuclear Operators (WANO), complemented by some others for day to day inspection purposes. In countries with a large number of plants, the regulatory body needs consistent tools to define policies to compare the safety performance of the nuclear power plants. In countries with a smaller number of plants, the regulatory body needs more specific means to evaluate plant operational safety performance. The general trend is to come up with a consensual approach to safety PIs at a high level.

2.2.2. Safety PIs recommended by national and international organizations to their members

Indicators recommended by national and international organizations are used mainly to monitor the overall plant safety performance, to make comparisons between plants, to encourage emulation of ‘best performance’ and to promote exchange of ‘good practices’ among plants. Such indicators are those of the Institute of Nuclear Power Operations (INPO) and WANO that are produced by the nuclear power plants affiliated to these organizations. These indicators are high level, ‘backward-looking’ indicators reported periodically, although much later than the actual period of time that they refer to. Therefore they are of little use in managing real time plant safety. On the other hand, the WANO indicators are the most ‘successful’, having remained almost the same since their introduction, and are reported by all utilities worldwide.

2.3. INDICATORS COLLECTED FROM NUCLEAR POWER PLANT INITIATIVES

The current set of WANO indicators is considered to be partial if overall plant safety performance has to be looked at. With this in mind, the managers of some nuclear power plants decided to develop a more complete set of SPIs at both the department/section level and the upper management level. These plants spent time and effort to convince section leaders and supervisors so as to have their active participation in the selection, definition and deployment of meaningful indicators for key plant processes and activities, to evaluate them periodically and take corrective actions if necessary. Despite the large number of indicators selected, this endeavour is an important self-assessment tool which provides valuable safety insights both at the operational and plant management levels.

The many projects and individual pilot studies presented at international technical meetings confirm the great interest of nuclear power plant operators in using PIs to manage safety. Successful applications are reported, especially in countries where centralized efforts have been made, and most of those are intended to supplement the WANO indicator system in order to satisfy specific needs. Or they contain the WANO indicators as a subset of the plant specific indicator system.

2.4. PROPOSED IAEA FRAMEWORK FOR DEVELOPING PLANT SPECIFIC SAFETY PIs

Since December 1995, IAEA activities in this area have focused on the development of a *framework for the establishment of nuclear power plant operational safety PIs.* This work was completed in 2000 and a report was published [3] that includes the results of pilot studies conducted at four nuclear power plants.

The objectives of these pilot studies were: (1) to validate the applicability, usefulness and viability of the approach; and (2) to obtain feedback regarding the difficulties found when implementing the programme. Each plant utilized the proposed indicator framework as a starting point; however, individual plant programmes were adapted to meet plant specific needs. Despite changes in the selection of indicators, all the plants involved chose to maintain the basic indicator oganization, thus providing validation for the concept. The participating plants concluded that the proposed framework provides a good approach for establishing a comprehensive operational safety PI programme.

In the proposed IAEA framework three important aspects were addressed — *nuclear power plant normal operation, nuclear power plant emergency operation,* and the *attitude of nuclear power plant personnel towards safety.* On this basis three key attributes were chosen that are associated with plants that operate safely:

(a) Plants operate smoothly,
(b) Plants operate with low risk,
(c) Plants operate with a positive safety attitude.

Because these attributes cannot be directly measured, the ‘indicator structure’ was expanded further until a level of easily quantifiable or directly measurable indicators was identified.

Using the attributes as a starting point for indicator development, *operational* safety PIs were identified. Below each attribute, *overall indicators* were established. Associated with each overall indicator were *strategic indicators*. Finally, each strategic indicator was supported by a set of specific indicators, most of which are already in use in the industry. Indicators were developed one level at a time to ensure that all relevant safety aspects of each attribute were covered.

The *overall or key indicators* were envisioned as providing an evaluation of relevant aspects of safety performance. *Strategic indicators* were intended to provide a bridge from overall to specific indicators. *Specific* or *plant specific indicators* represented quantifiable measures of performance. Specific indicators were chosen for their ability to identify declining performance trends or problem areas quickly so that after proper investigation, management could take corrective actions to prevent further performance degradation.

The IAEA started a Co-ordinated Research Project (CRP) on the development and application of operational safety PIs in December 1999. Eleven nuclear power plant/utility organizations from nine countries are participating in this project. The general aim is to assist nuclear power plants worldwide to develop and implement their own plant specific operational safety PI programmes. The CRP participants are exchanging information and discussing topics such as general principles for the establishment and use of safety PI programmes, selection of specific indicators, principles for indicator definition (purpose, objective, description and formula), goals and thresholds for low level (specific) and high level (strategic and overall) indicators, how to use indicator systems, computerized systems to support indicator programmes, data needs and problems, benchmarking, credibility of the indicators, and use of safety PIs for communication with regulatory authorities and the public.

3. PROBLEMS IDENTIFIED AND ISSUES TO BE RESOLVED

So far, there has been a lack of indicators that can be more closely tied to the safety culture of an organization. Usually, the strength of the safety culture is inferred from the results shown in operational safety PIs. To achieve a better understanding of the influence of attitudinal and other cultural factors on safety performance, there is a need for additional safety culture indicators.

At the same time, it must be recognized that safety culture is a complex concept and there is no simple indicator that measures its state. The multilevel nature of culture, and the tacit nature of some of the levels (basic assumptions), increase the difficulty of measurement. This means that a broad range of indicators, some of which may be more subjective in form than others, is necessary to gain useful information about the state of safety culture in an organization. The only practical way forward is to identify a portfolio of indicators that measure the important characteristics of a positive safety culture. It is also important to recognize the close connection between the management of safety and safety culture.

3.1. MANAGEMENT OF SAFETY AND SAFETY CULTURE

The essential components of an effective safety management system can be described in various ways. Some of the desirable attributes of an effective safety management system are described in INSAG-13 [1]. Through a set of questions covering the observable features of an effective safety management system, a basis is provided for judging the effectiveness of the system. The areas covered through these types of assessments can be further developed into more quantitative indicators.

To oversee safety culture, difficulties should not to be underestimated, since so many of the required characteristics lie below the surface. It is believed that in order to properly assess safety culture, it is necessary to consider various means of evaluation. Therefore, comprehensive questionnaires, structured interviews and checks on management and people involved in safety related work, plant documentation and procedures could reveal strengths or weaknesses in an organization.

The key elements often covered in questionnaires and interviews to assess safety culture could also be developed further into indicators. Considering that the safety culture of an organization reveals itself at various levels (visible products and behaviours, stated values and basic assumptions, beliefs and perceptions), it may be more or less difficult to establish indicators. What is typically assessed through questionnaires and interviews are employee perceptions of various safety management practices. A full assessment in this way usually covers a number of key elements. Examples of these elements, which can be further developed into indicators, are: top management commitment to safety, visible leadership, high priority of safety, openness and communication, systematic approach to safety, sufficient and competent staff, compliance with regulations and procedures, etc.

In recent years, several nuclear organizations have experienced degradations and shortcomings in their safety management processes. Based on a review of these experiences [4–6], some common symptoms and causes have emerged. There is often a delay between the development of weaknesses and the occurrence of an event involving a significant safety consequence. By being alert to the early warning signs, corrective action can be taken in sufficient time to avoid adverse safety consequences. Both the management and regulators must pay attention to signs of potential weakness. The management of an organization should pay particular attention to monitoring for these symptoms of a weakening safety culture in their self-assessment process. For some of the symptoms it may be possible to develop safety PIs that will be of practical value in detecting adverse trends from both a utility and regulatory perspective [7].

Finally, regulators themselves should be technically competent, have high safety culture and standards for auditing their own work, deal with operators in a professional manner and show good judgement in evaluations and enforcement actions. Possible indicators are: organizational commitment to the priority of safety matters, clear lines of responsibility, staff competence, good internal communication, clear guidance for inspections and evaluations of safety cases, well established and known systems for acceptance criteria, timely regulatory decisions, enforcement actions in accordance with the real importance of events and circumstances, and use of risk analysis and performance data in decision making. An extensive list of potential indicators of regulatory effectiveness has been developed through the IAEA peer discussions on regulatory practices [8].

3.2. GENERAL ISSUES

3.2.1. Need for and feasibility of an international system

The possibility, feasibility and usefulness of a comprehensive set of safety PIs agreed internationally is often discussed at forums where issues related to nuclear power plant operational safety and nuclear regulation are discussed.

Before such a significant effort is undertaken, there are issues to be clarified and questions that need answers. Some examples are listed below:

— Would the establishment of a set of safety PIs agreed at an international level be feasible?
— Would this set be useful (e.g. would it be useful for regulatory authorities)? Would it be useful as a means to report to the Nuclear Safety Convention? Would it be useful for benchmarking among nuclear power plants?
— Would not the difficulties of getting worldwide agreement on a set of indicators and establishing an efficient system for reporting and evaluation be far more significant than the benefit obtained from such an effort?
— Who would be the counterparts in this effort, i.e. nuclear power plants or regulatory organizations?
— Which international organization would be responsible for compiling, analysing and comparing all the information received from the counterparts in the countries?
— Would this information be made public?

Over the past two years, WANO has conducted a review of its set of PIs in order to see if there is any need to make a change. As a result of this review, WANO decided that it will no longer use either the Thermal Performance Indicator or the Volume of Radioactive Waste. Additionally, some clarifications to definitions were developed. The review groups also examined the development of a risk based indicator for safety systems, as well as that of an event based indicator. Although satisfactory indicators were not developed for these two areas, they remain of interest for future improvements to the set of WANO PIs.

An international system of SPIs could also be developed for use by regulatory bodies. It would be necessary to reach consensus on a small set of SPIs in the areas of plant performance stability, reliability of safety systems, integrity of barriers and radiological impact. The IAEA could provide a forum for regulators and operators to compare safety performance and identify strengths and weaknesses. Besides, regulators and operators would have a tool to provide information to the public and help to increase trust.

3.2.2. Plant management needs

The plant management needs to have a complete picture of the safety performance of the plant in order to detect early symptoms of deterioration and to be able to divert resources to where they are most required. Therefore, there is a need for a comprehensive set of safety PIs, encompassing indicators in all the areas that directly or indirectly affect safety, to be used by the plant for self- assessment. These indicators would be used at the plant management level. Thus, this set would, in principle, be absolutely plant specific and would evolve with time to reflect the need to focus in great depth on specific topics for a period of time in order to improve safety performance in specific areas.

In this regard, it is necessary to understand why there are still nuclear power plants that have not implemented indicators to monitor performance in all areas that can impact safety.

Further thought needs to be given to the impact of the corporate organization on plant safety. Safety performance indicators applied to the corporate organization can be important for monitoring key aspects where its policies and decisions impact at plant level. Also, the corporate level should monitor a set of PIs from each of its nuclear power plants to check for signs of deteriorating performance, progress towards agreed goals, etc.

3.2.3. Regulatory use of safety PIs

Although individual regulators use various approaches to safety PIs, it is believed that a small set of indicators covering the key cornerstones could be agreed upon. The issue is related to what would be those cornerstones and the complete set of indicators required by regulatory bodies. Should this be a subset of a wider set being collected by the plants? Are there any requirements for special indicators? Should a set of indicators for regulatory use be defined only after the plants have gained sufficient experience with the collection and evaluation of safety indicators, or should they be defined upfront to guide the formulation of plant indicator programmes?

The importance of baseline regulatory and management inspection programmes should be recognized. Indicators cannot do the job alone in any context. There is no substitute for sound inspection involvement. The indicators can help direct inspection efforts and possible supplements to a sound baseline programme, but indicators can never totally replace these efforts. Some countries have established working groups of regulators, nuclear power plant operators and R&D institutions to pursue these developments, looking for consensus among licensees and regulators.

3.2.4. Public communication

It is a function of both the operating organization and the regulatory body to provide timely and accurate public information on the safety performance and on safety issues of nuclear power plants. Therefore, either the same set of Safety PIs developed by the regulatory body or a subset of these indicators, carefully chosen in order to clearly transmit the correct messages to the public, should be used. The information may be communicated through public information centres and also through periodic written reports to be presented to the government and public institutions. The following are some pertinent issues:

- How does one select and use safety PIs to communicate nuclear safety effectively outside the nuclear community?
- Should only easily understandable indicators be used for communication with the public in order to avoid misunderstanding and misinterpretation?
- Should only long term indicator trends rather than absolute values be used?

3.3. SPECIFIC ISSUES

The following are specific issues that have been identified in the pilot studies conducted within the framework of IAEA activities and are discussed in greater detail in Ref. [3]:

- *Selection of indicators:* Depending upon their use for regulatory purposes, operating organization and plant management purposes or plant department supervisor purposes, the number of safety PIs is going to be different. Most important is that the selection of indicators be made after a complete and thoughtful revision of key processes and activities by those who have responsibilities and therefore are involved in the processes. It should be taken into account that a reasonable and manageable set of indicators needs to be developed covering the important aspects of the safety management system and following a hierarchical structure. Depending upon their use for decision making, these indicators need to be at the appropriate organizational and institutional level.
- *Definition of indicators:* A clear and simple definition of each indicator has to be established as a key part of the programme. The future owners of the data collected should also be involved in the definition of procedures and methods of calculation of indicators. When developing international indicators, an even more careful definition, and clear and detailed explanation, including examples and data collection requirements, should be provided such that anyone can

understand how to calculate and compare meaningful results among nuclear power plants.

— *Identification of goals, thresholds and performance bands:* Goals represent the standards or levels the plant wants to follow, maintain, or achieve. Indicators can provide useful information on a continuous improvement programme or an early warning of declining performance. The process again requires discussion and negotiation, with the participation of the owners of the indicators and management intervention to identify what constitutes a reasonable expectation for the performance of each indicator.

— *Data display and interpretation:* Usually data covering a five year period are sufficient for the purpose of evaluating the indicators. Some indicators provide valuable information when viewed separately, but when viewed together they can provide additional insights. Therefore it is recommended that methods be developed to enhance the value of the model by aggregating the performance across a number of indicators in relevant groups so that a 'big picture' at the higher level can emerge regarding the organization's strategic and overall safety performance. Although the value of the composite rating is not significant, it allows for visualization and trending of overall performance over time. Each specific indicator should be evaluated against the established goal and the results may be presented through graphic displays of individual indicators, colour window displays or trend display.

— *Logistics and other resources required to support programme development:* Depending on the starting point of each plant the effort to implement an operational safety indicators programme may be more or less significant. However, because plants already have some kind of data collection and performance monitoring system, it is believed that only small additional resources are required. However, the implementation process implies an additional effort by the plant above all to select and define the indicators and establish the goals.

In the frame work of the IAEA CRP referred to in Section 2.4, the concept of a model for safety PI evaluation is being developed based on two regions for the indicator values. These are satisfactory (acceptable) and unsatisfactory (unacceptable). The acceptability region is further divided into excellence, operating and warning zones.

The unsatisfactory/unacceptability region is where indicator values are considered by the management as signs of unsatisfactory performance. If the indicator is governed by Technical Specifications or regulatory requirements, the region is termed unacceptable; otherwise it is termed unsatisfactory.

In order to keep performance levels in the acceptable region, it is required that a warning be generated before the limit is reached. This warning zone is defined by the unsatisfactory limit and a working goal that the management expects to achieve in a given year. It is therefore a short term goal.

The company's vision for an individual indicator is the long term goal, also called the 'strategic goal'. The band between the working (annual) goal and the vision defines the operating zone. The zone beyond the vision represents the excellent results.

It is noted that the working goal may change from year to year as the performance improves. The intention is to have an achievable short term working goal which moves closer to the vision. The vision, on the other hand, represents a strategic goal which remains stable and is open to change only in the long term (for instance after five years).

There are several ways to determine the threshold values. It is up to the nuclear power plant to determine the most suitable ones for its plant specific use.

The scheme for the selection of the band thresholds considers two cases, depending on whether or not the unacceptable region is identified by regulatory requirements or by the safety case.

In the first case the unacceptable limit (between warning and unacceptable zones) should be set by the required limit established by the regulator or plant safety case documentation. The annual plan (between the warning and operating zone) should be the value set by the plant management. A possible warning limit (working goal) could be 80 or 120% of the unacceptable limit, depending on whether low or high is good. This has to be discussed with the 'owner' of the indicator and accepted by the management. The vision or strategic goal (between the operating and excellent zones) should be the value set by the company's vision or strategy.

In the latter case, when the unacceptable region is not identified by regulatory requirements or by the safety case, an analysis of historical data should be performed to obtain percentile information. The unsatisfactory limit (between the warning and unsatisfactory zones) could be set by the 50th percentile. The annual plan (between the warning and operating zones) could be the value set by the 40th percentile (if low is good). The vision or strategic goal (between the operating and excellent zones) could be the value set by the 20th percentile. In the event that enough data is not available, expert judgement would have to be used to select the various limits once the company vision (strategy goal) has been set by the management.

An alternative option is to set the unsatisfactory region in the same way but set the vision or strategy goal (between the operating and excellent zones) as the short term one year strategy. This would mean that the colour indicator would provide a more positive position. The annual plan (between the warning and operating zones) should be the value set as an initial warning level.

It needs to be recognized that when comparisons between previous years and the current year are performed, colour indications may indicate deterioration. The indicator value may in fact have improved or have been stable, but the colour code may have been brought down as a result of changing annual plan targets. This is deemed acceptable because the indication colour is established by the relevant company values set in that year. When a comparison is required that utilizes the colour indicator, previous years should be re-evaluated against current thresholds. This will provide a common base for comparison.

4. RECOMMENDATIONS FOR STRATEGIC ACTIONS/PRIORITIES FOR FUTURE WORK

The following recommendations are proposed for strategic actions within four domains:

Nuclear power plants

Nuclear power plants and corporate organizations need to have a complete ‘picture’ of a safety management system and its monitoring performance so as to manage what can be qualitatively and quantitatively measured. Therefore:

(1) The management of nuclear power plants is encouraged to use the attributes and overall and strategic indicators of the IAEA’s proposed framework in their safety management decision making process. The attribute corresponding to a positive safety attitude should be complemented by a periodic qualitative evaluation of the organization’s safety culture. The management also needs to review safety PIs at the nuclear power plant level.

(2) For plant specific operational safety indicators, nuclear power plant management should consider committing plant department/section leaders to seeking a selection of indicators, within the umbrella of the IAEA’s proposed framework.

Regulators

(3) The set of safety PIs to be used by the regulatory bodies can be derived as a subset from the indicators of the IAEA’s proposed framework. The subset should cover, at a minimum, the key cornerstones of operational safety performance.

(4) Regulator and licensee representatives should meet in an international forum to agree upon this set of safety PIs. The set has to be clearly defined, as should the methods for gathering plant data and calculating the indicators.

IAEA

The IAEA has devoted significant resources to the development and improvement of operational safety management systems, safety culture and safety PIs, and it should continue in this endeavour, by:

(5) Continuing CRPs in different regions of the world to help nuclear power plant management in the development of plant operational safety indicators according to the IAEA's proposed framework.
(6) Serving as a forum for nuclear power plant regulators and operators to achieve the goal stated in item (4). The work by the IAEA should be initiated as soon as possible and be completed in 2003, to accomplish this goal. Procedures should be developed that can be used by both the operators and the regulators to collect and analyse data for safety PIs.

International level

The well known set of WANO PIs has been used internationally for many years. While these indicators are well defined, they do not address the issue of operational safety performance. Therefore it is recommended that:

(7) The set of safety indicators to be developed under the auspices of the IAEA be 'institutionalized' as a more complete set, to be used not only by regulatory bodies, but also for public information purposes and for inclusion in publicly available reports issued periodically by regulators to inform the government and public institutions. Consideration should be given to the IAEA collecting and making the indicators internationally available on an annual basis.

A basis for constructing a set of safety PIs for international use is proposed in the Annex.

5. QUESTIONS TO THE CONFERENCE

(1) Can a threshold be established to compare safety data with risk relevance?

(2) Can an international system or 'menu' of safety PIs be used in the framework of the national reports prepared for the Convention on Nuclear Safety?

(3) Should the set of internationally agreed safety PIs be used for public information?

REFERENCES

[1] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Management of Operational Safety of Nuclear Power Plants, INSAG-13, IAEA, Vienna (1999).

[2] NUCLEAR ENERGY INSTITUTE, Regulatory Assessment Performance Indicator Guidelines, NEI 99-02, NEI, Washington, DC (2000).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Safety Performance Indicators for Nuclear Power Plants, IAEA-TECDOC-1141, IAEA, Vienna (2000).

[4] MACTAVISH, B.D., et al., "Shortcomings in safety management: symptoms, causes and recovery", Topical Issues in Nuclear, Radiation and Radioactive Waste Safety (Proc. Conf. Vienna, 1998), IAEA, Vienna (1998).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Developing Safety Culture in Nuclear Activities: Practical Suggestions to Assist Progress, Safety Reports Series No. 11, IAEA, Vienna (1998).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Culture Self-Assessment: Highlights and Good Practices (unpublished).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Reference Material for the IAEA Safety Culture Services (unpublished).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Assessment of Regulatory Effectiveness, Peer Discussions on Regulatory Practices No. 4, IAEA, Vienna (1999).

Annex

A BASIS FOR CONSTRUCTING A SET OF SAFETY PIs BASED ON THE THREE IAEA ATTRIBUTES

Threshold considerations for the indicators related to the three IAEA attributes should be keyed to worldwide performance statistics. Nominal performance might be defined as greater than 90% of the mean worldwide. A heightened awareness performance band might be established between 75 and 90% of the worldwide median, and performance at less than 75% could be considered in the safety concern range. Therefore, bands of 'nominal', 'heightened awareness' and 'safety concern' could be established for the various safety PIs.

A. PLANT OPERATES SMOOTHLY

— *Unplanned power transients (>20%).* This factor would include all scrams, both manual and automatic, and power transients greater than 20% that are initiated by urgent maintenance needs less than 72 hours after discovery. Management or dispatch directed transients not associated with urgent maintenance would not be included.
— *Reactor coolant system (RCS) integrity.* RCS identified or total leakage.

B. PLANT OPERATES WITH LOW RISK

— *Challenges to safety systems.* The number of demands to the reactor protection, emergency core cooling, residual heat removal, and electric power supply systems.
— *Safety system performance.* The number of hours and times a safety system is unavailable. Availability may be a preferred measure to maintain a positive safety viewpoint.

C. PLANT OPERATES WITH A POSITIVE SAFETY ATTITUDE

— *Industrial safety accident rate.* This is used as an indicator of safety attitudes. It is easily measured and internationally understood. Performance values under this indicator should be very low and should be a small fraction of the accident rates evident for all industrialized activities in a national context. It is a WANO indicator but not reported by all sites.

— *Occupational radiation safety.* NEI 99-02 [2] contains more detailed information on this indicator, which sums occurrences of non-conformance events in high radiation areas, very high radiation areas and unintended exposures.
— *Public radiation safety.* This indicator counts occurrences of radiological effluents, both gaseous and liquid, in excess of prescribed values. It is explained fully in NEI 99-02.
— *Self-identification fraction.* Problems are often identified at nuclear power plants by those external to the facility such as regulators, peer reviewers or assistance teams. In addition, problems may be identified by internal teams whose primary responsibility is inspection rather than operation. It is a sign of a good safety culture if the majority of problems identified at the facility are 'self-identified' by internal staff with primary responsibility for operations and maintenance. Problems identified without the benefit of 'self-revealing' events are particularly beneficial. This indicator is highly dependent on the maturity of the nuclear power plant's self-assessment and corrective action programmes, as well as the robust nature of external and internal dedicated inspection forces. However, where they exist a ratio of self-identified problems to all identified problems greater than 0.5 is an indication of a safety oriented culture.

— *Safety culture indicators*
  - Activity indicators. A set of indicators was developed and is in use in the Forum of Nuclear Co-operation in Asia. Indicators deal with: communication between management and employees on safety culture; activities on safety culture involving regulators and contractors; systematic analysis of incidents to determine human factors and lessons; safety culture training activities; surveys to determine employee attitudes and the adequacy of resources allocated to promoting safety culture.
  - Weakening safety culture. A list of symptoms from both the organization's and regulator's perspective is suggested in Ref. [7]. The symptoms are related to a model which considers the stages of organizational decline, each of increasing severe consequence. It may be possible to develop indicators for some of the symptoms. Examples are procedures not properly followed, incidents not analysed in depth; lessons not learned; increasing number of violations; increasing backlog of corrective actions; and failure to deal with the findings of external safety reviews.

Keynote Paper

SAFETY INDICATORS: INITIATORS FOR LEARNING AND ACTION

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Abstract

SAFETY INDICATORS: INITIATORS FOR LEARNING AND ACTION.

While the Sydkraft Safety Council promotes proactive safety work at the Barsebäck and Oskarshamn nuclear power plants, it also monitors and evaluates the safety management work of the plants at the corporate level. To aid it in this work, the Council has chosen a limited number of safety performance indicators. The Council requirements on the indicators have been that they should assist in identifying precursors and the tendencies of parameters to deviate before they develop and seriously affect safety in the long term. To follow indicator trends is considered more valuable by the Council than to study absolute indicator values. The Safety Council takes the view that safety indicators will stimulate plant organizations to continuously improve their safety related work. Experience has shown that improvements have taken place in areas that are of fundamental importance for efficient safety work. Finally, the use of safety indicators at the Safety Council level has lead to an increased and more profitable use of safety indicators at different levels in the plant organizations.

1. INTRODUCTION

Safety performance indicators (PIs) are being used by the nuclear industry to a greater extent today than only five to ten years ago. More and more nuclear plants also realize that there are benefits in using these types of indicators. The increasing utilization of indicators does not necessarily mean that all users benefit from safety indicators in the same way. The purpose of this presentation is to describe how safety PIs are used at the corporate level in the Safety Council of Sydkraft AB, and to provide a few examples of how other nuclear actors in Sweden use indicators in their safety management activities.

2. BACKGROUND

Sydkraft AB is the majority owner of OKG AB, which is the operator of the three units in Oskarshamn. When the Sydkraft Safety Council was established, almost ten years ago, Sydkraft was also the sole owner of the two Barsebäck units. In connection with the premature decommissioning of Barsebäck 1 in 1999 and the settlement between Vattenfall AB, Sydkraft AB and the Swedish Government, the Barsebäck plant became a part of the Ringhals group with its four reactors. On the basis of an agreement, Sydkraft AB became a minority owner (about one fourth) of the Ringhals group and consequently still has an interest in the operation of the second Barsebäck unit. The complex agreement also means that Sydkraft indirectly is holding the operating license of the Barsebäck plant and will be responsible for the future dismantling of the two units. This explains why the Sydkraft Safety Council maintains its focus on the operating unit of Barsebäck, in addition to the units in Oskarshamn.

The reason behind the establishment of the Sydkraft Safety Council was a recommendation put forward in a study of the safety culture of the nuclear activities of the Sydkraft Corporation, including the plants in Barsebäck and Oskarshamn. The study had been prompted by the incident in Barsebäck in 1992, when the strainers in the emergency core cooling system were clogged by insulation material after an activation of safety relief valves in the primary containment. One of the conclusions of the study was that a Quality and Safety Council be established to act jointly for the Barsebäck and Oskarshamn plants in order inter alia to “consider and advise on all important safety and quality matters”.

It was agreed that the objective of the Sydkraft Safety Council was to promote proactive and long term work with safety at the Barsebäck and Oskarshamn plants, and in particular to:

— Monitor adherence to the Sydkraft Safety Policy,
— Monitor and evaluate external experiences and R&D results and suggest areas for improvements or further studies,
— Judge if the Supervisory Boards and the Presidents are fulfilling their safety related responsibilities in a satisfactory manner.

The Council is reporting its observations to the Supervisory Boards of the companies owning OKG AB and the Sydkraft part of Barsebäck, as well as to the top management of the Sydkraft Group. The Safety Council is composed of eight to ten members, including representatives of the Sydkraft Corporation and the nuclear plants, as well as of members from outside the Sydkraft Group. The Council meets three times annually.

3. SAFETY PIs USED

The Safety Council concluded at an early stage that it could benefit from the review of a number of selected safety PIs to monitor the safety work at the company's nuclear plants. The first choice of indicators was a mixture of six well established PIs of the World Association of Nuclear Operators (WANO) and four specific indicators developed primarily for use by the Safety Council. Experience gained in the Safety Council led after a while to the exclusion of three of the WANO indicators, as they were found to be less purposeful in this context. One of the specific indicators was also eliminated after having fulfilled its purpose. At the same time, new specific indicators were developed and supplied to the indicator set. This shows that there is an ongoing process of questioning and continuously improving the set and design of applied safety indicators.

The current set of indicators consists of the following WANO indicators:

— Unplanned automatic scrams per 7000 hours critical (UA7),
— Chemistry performance indicator (CPI),
— Collective radiation exposure (CRE).

The WANO indicators are considered well known by everyone in the nuclear field and, therefore, no definitions are given here. The specific safety indicators used by the Sydkraft Safety Council are:

— **Temporary modifications index.**
Definition: The sum of days during which temporary operating procedures have been in use during the measuring period divided by the number of days during the measuring period.
Purpose: To measure the extent of temporary measures being used and what efforts are made in order to reduce the durability of the measures.

— **Fault recurrence index.**
Definition: The number of LERs in a unit that are considered a recurrence compared with reported LERs from all units at the site during the previous three years, divided by the total number of LERs for the unit in question during the measuring period.
Purpose: To measure the extent of recurrence of LERs and thereby the ambition and ability of the organization to identify root causes and take corrective actions that prevent a recurrence.

- **Quality audit index.**
  Definition: The number of agreed quality audit remarks at performed audits during a year which have been taken care of properly within an agreed time, divided by the total number of agreed remarks during the same year.
  Purpose: To monitor the disposition of the organization to correct identified deficiencies, but also to measure the number of quality audit remarks.
- **Safety index.**
  Definition: The sum of the relations between the real repair time in connection with occurred LERs and the allowed repair time according to the Technical Specifications for the same LERs.
  Purpose: To monitor roughly the availability of safety systems and components, and to measure the efficiency of corrective maintenance steps.
- **'Man, technique, organization' (MTO) index.**
  Definition: The number of MTO related LERs according to an agreed model for classification of events.
  Purpose: To estimate the number of LERs that are MTO related.
- **Fuel damage index.**
  Definition: The number of damaged fuel rods during an operating cycle. (The time period between refuelling outages.)
  Purpose: To obtain an understanding of the reliability and integrity of the fuel.
- **Work accident index.**
  Definition: The sum of the points received for work related accidents and incidents occurring at the site according to a specific score table. Consideration is given to the degree of seriousness and the possibility of preventing an accident or incident.
  Purpose: To measure the extent of work accidents and incidents, and to follow the result of steps taken to minimize such events.

Three of the specific safety indicators are shown in the Appendix.

When searching for indicators, the Safety Council felt that its indicators should focus on precursors and deviations with the objective that they should act as an incentive for continuous safety improvements at the plants. The fundamental thought behind this view is that if anything goes wrong there should be no deficiencies that could worsen the situation.

As indicated by the definitions above, some of the indicators are only calculated and reported once a year, while most are reported biannually to the Safety Council meetings. In the reports to the Sydkraft Safety Council, the indicator graphs are completed with analyses of the achieved indicator values. The results are discussed during the meetings and represent a part of the information that the Council uses in its monitoring of the safety management work of the plants.

4. OBJECTIVES AND USE OF THE SYDKRAFT SAFETY COUNCIL INDICATORS

The Sydkraft Safety Council has decided to use a selected and limited number of safety PIs. In other words, it has no intention of following indicators that cover the entire safety field simply for the reasons that it is neither the task of the Safety Council to try to measure the safety performance or safety level of the plants nor to solely use safety indicators in its review of safety management at the plants. The Council is of the opinion that indicators shall indicate, i.e. they shall send signals when there are small signs of negative trends. The Safety Council indicators are therefore primarily developed to be chosen from indicators that are considered to be proactive. The objective of the indicators is that they should show whether there are tendencies, for instance, of complacency or weakening in the organization or that the safety culture is deteriorating. These aspects clarify why indicators concerning technical deficiencies are considered less relevant for Safety Council work and that focus is more on failures occurring within the plant organizations and management areas. Important, however, is that indications of emerging deviations appear much before the acceptance levels are reached, so that counteractions can be taken in order to reverse the trends.

The safety culture status of the plants, which is of great interest for the Council, can be regarded as an indicator itself. However, in many utilities/plants the safety culture situation is today often reviewed and measured by its own set of indicators. The Sydkraft Safety Council has decided to benefit from the current safety PIs when gathering information on safety culture status, but also to rely on other means of information.

The WANO indicators do not fulfil the requirement to be proactive; they are, rather, lagging or reactive. On the other hand, they have the advantage of being general and used by the entire nuclear community, which allows them to be compared all over the world. This type of general indicator can therefore be justified, particularly when there are signs that a plant tends to compare its performance only with itself.

In most cases the absolute values of the Safety Council indicators have none or very limited value for the Council. It is rather the trend that is considered essential and important. As mentioned, safety PIs are not regarded as measures of safety or safety culture at the plants, but they serve as initiators for further actions. The indicator results often generate a number of questions, which in turn require deeper analyses of a subject or an area. If these analyses show safety degradation, countermeasures are, of course, requested.

The Sydkraft Safety Council does not set any indicator goals, which is the consequence of the Council having very little interest in absolute indicator values. The reason is simply that the Council is not operative, since it is supplementary to the Safety Review Committees of the plants. The tasks of the Council are rather: (a) to inform its stakeholders about its conclusions and views on safety matters based on the information obtained from the safety indicators and from other sources; and (b) try to influence the plant management to take the appropriate measures to improve long term performance.

The establishment and follow up of a number of safety PIs by the Sydkraft Safety Council have also served as an invitation to the plant managements to use the indicators, and encourage them and their staff to benefit from the use of all types of safety indicators at different levels of the organization.

5. EXPERIENCE WITH THE USE OF SYDKRAFT SAFETY COUNCIL INDICATORS

The response and engagement of the plants was not immediate and positive when the indicators were introduced. Progressively, however, they have gained acceptance and been adhered to, to the extent that today most of the Safety Council indicators are part of the plants' set of PIs. In some cases the plants are also setting goals in order to increase the focus on the indicators and to use them as management tools. The experience is that the implementation and full utilization of new tools and methods often takes more time and effort than was initially expected.

Continuous improvements are a prime concern for the Safety Council when considering safety issues and the same goes for its approach to the safety PIs. Consequently, the set of indicators used has changed over the years and some of the indicator definitions have been modified slightly in order to make them as beneficial as possible for Safety Council use. One of the original indicators dealt with the tightness of isolation valves with regard to the primary containment. These valves are leak-tested annually before and after service of the valves and the indicator revealed that the total amount of leakage before service often was unacceptably high, and that the test procedures and the interpretation of the regulations varied between the plants. This example shows that with better awareness of the situation owing to the information provided by the indicator, plant management focused on the issue and took actions to improve the situation. Having reached this goal, the Safety Council concluded that this particular indicator did not serve any further purpose and had it removed from its list of indicators.

6. ALTERNATIVE USE OF SAFETY PIs IN SWEDEN

The other big actor in the Swedish nuclear field, Vattenfall AB — the majority owner of the Ringhals and Forsmark plants — has a somewhat different approach to safety indicators used at the corporate level, where a number of indicators comparable with the Sydkraft ones are presented. The difference is that these indicators cover such areas as:

— availability,
— unplanned unavailability,
— unplanned scrams,
— unavailability of safety systems,
— fuel performance,
— collective radiation exposure.

These indicators are not only reported individually, but are also aggregated into one safety index.

Ringhals has developed its own indicator system based on nine indicators. These are different from those reported at the corporate level, and one of them is a safety culture questionnaire. They are aggregated into five indexes:

— INES,
— Technical issues,
— Organizational issues,
— Safety culture.

A final aggregation of these four indexes creates the Ringhals Safety Index (RSI).

Both the Vattenfall and Ringhals indicator presentations are carried out by the generally used annunciator window method, using traffic light colours for each indicator and index. This gives a high degree of transparency, which is considered necessary when indicators are aggregated into one final index.

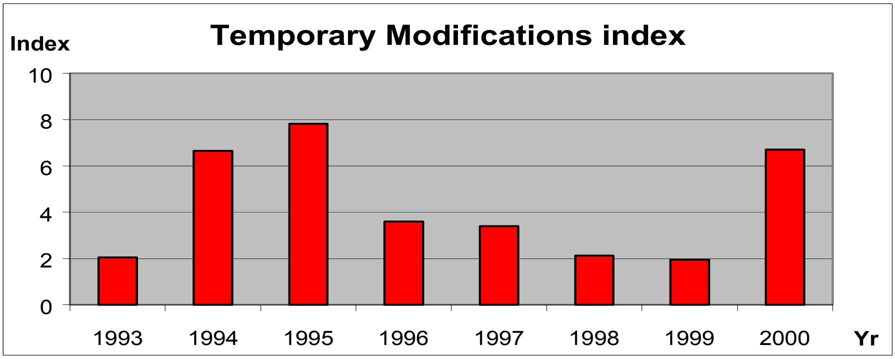
In the case of Ringhals, the transparency has a certain importance as the result is communicated not only to the personnel in the Ringhals organization, but is also used in the information that is disseminated to the local public. A warning flag should be raised in this context as there is always a risk of misinterpretation of indicator results if they are not accompanied by a manual that explains the information. Besides, indicators never give a complete picture of the safety status, not even for a trained receiver of the information.

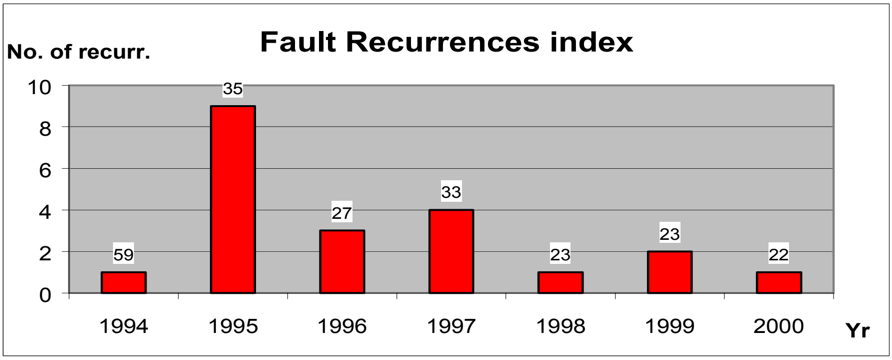
7. CONCLUSIONS

Safety indicators have proved to be one of a set of useful tools for the Sydkraft Safety Council in its promotion of proactive safety work at the Barsebäck and Oskarshamn plants. The increased use of safety indicators has resulted in improvements in areas that are considered fundamental for good safety, such as root cause analysis and minimization of the number of temporary modifications.

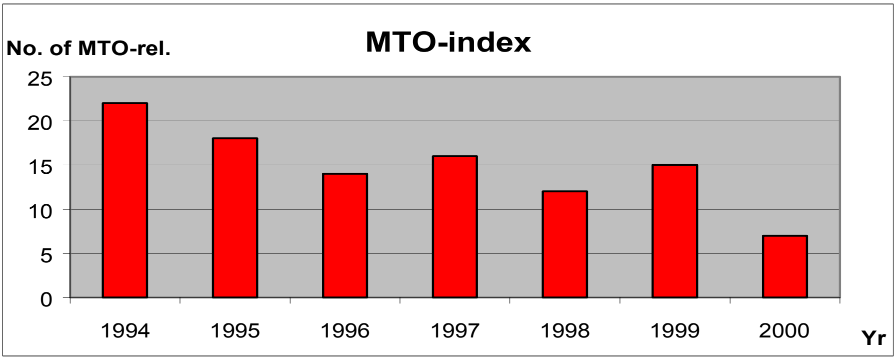
The utilization of safety indicators is, however, not an instrument that pays off immediately. It takes time to have indicators well implemented and accepted and their full benefit is not obtained until the trends become reliable.

Appendix
EXAMPLES OF SAFETY INDICATOR TREND GRAPHS





The figure above the column indicates the number of LERs



Keynote Paper

NRC'S EXPERIENCE WITH PERFORMANCE INDICATORS IN THE REVISED REACTOR OVERSIGHT PROCESS

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Abstract

NRC'S EXPERIENCE WITH PERFORMANCE INDICATORS IN THE REVISED REACTOR OVERSIGHT PROCESS.

Over the last several years, the United States Nuclear Regulatory Commission (NRC) has developed and implemented a revised Reactor Oversight Process (ROP). Major factors in pursuing this initiative included the improved safety performance of US nuclear power plants over the past decade, as well as critical feedback from many stakeholders regarding the NRC's performance assessment process. After conducting a pilot programme at 13 sites in 1999, the NRC recently completed the first year of implementing the ROP at all 103 commercial nuclear power plants. In July 2001, the NRC staff reported to the Commission the results and lessons learned from this experience. The paper provides the key insights the NRC gained relative to the application of performance indicators as part of the NRC's revised ROP.

1. BACKGROUND

Before describing the insights the NRC gained from initial implementation of the Reactor Oversight Process (ROP), it is worthwhile to provide an overview of the ROP so that the reader has an appropriate background on the process. Several years ago, the Commission directed the staff to develop an oversight process that was more risk informed, understandable, predictable and objective. A top–down hierarchical approach was used to generate the overall framework of the process. Central to being able to meet these criteria was the application of performance indicators (PIs).

The regulatory framework (Fig. 1) starts with the agency's overall mission — to assure public health and safety. The NRC's strategic plan identifies those areas of licensee performance for which the NRC has regulatory responsibility. These are

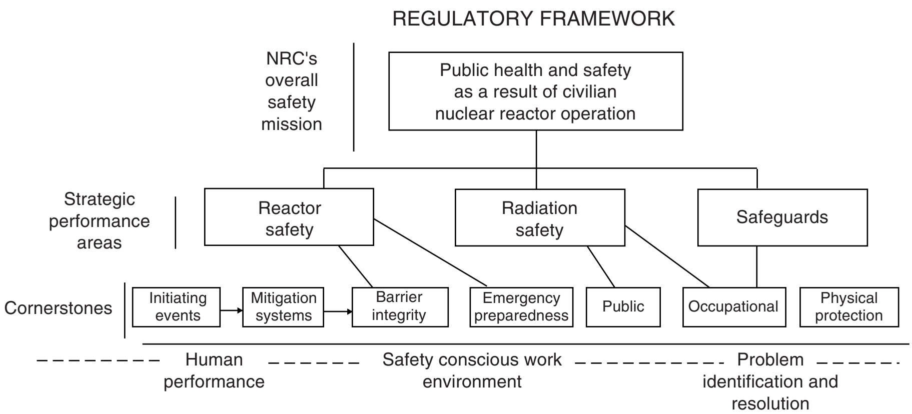

FIG.1 The regulatory framework of the NRC.

represented by the strategic areas of reactor safety, radiation safety and safeguards. The NRC then identified the most important elements in each of these strategic performance areas, which form the fundamental building blocks of the framework. These are referred to as 'safety cornerstones'. Acceptable performance by a licensee in each of these cornerstones should provide assurance that the overall goal of the adequate protection of public health and safety is met. The cornerstones were chosen to: (1) limit initiating events; (2) ensure the availability, reliability and capability of mitigating systems; (3) ensure the integrity of reactor safety barriers; (4) ensure the adequacy of emergency preparedness functions; (5) protect the public and plant workers from exposure to radiation; and (6) provide assurance of the effectiveness of physical protection systems. Underlying the regulatory framework are three performance areas, which have been identified as cross-cutting issues. These are considered to be elements of a licensee's performance that are prevalent in each of the cornerstones, and about which the NRC gathers insights based on its inspection and PI programmes.

The NRC then applied a top–down, risk informed approach to establish how to assess performance in each cornerstone. This required it to identify: (1) the objective and scope of each cornerstone; (2) the important attributes of licensee performance in each cornerstone; and (3) what should be measured to ensure that the cornerstone objectives are met. Once this was accomplished, it could then be determined what areas could effectively be monitored using PIs and what other information was needed to supplement areas where PIs were not sufficient. It is important to recognize that the inspection programme and the PIs are not intended to provide complete coverage of every aspect of plant operation. They are intended to provide a broad sampling of information to aid the NRC in assessing licensee performance in each cornerstone.

2. DEVELOPING AND INTEGRATING PIs INTO THE ROP

The incorporation of PIs into its oversight framework was a significant change for the NRC. Previously, the NRC's use of PIs was limited to a set of metrics maintained by the former Office for Analysis and Evaluation of Operational Data (AEOD) that provided information but did not play a direct operational assessment role. The NRC faced several key challenges in integrating PIs into its regulatory framework. The first was identifying metrics for each cornerstone. Where appropriate, the staff incorporated, wholly or in part, several of the existing AEOD and World Association of Nuclear Operators (WANO) PIs, such as equipment unavailability and unplanned scrams. However, the staff developed a number of new PIs, particularly in areas such as emergency preparedness and safeguards. There were six criteria the NRC considered in its selection of appropriate PIs: (1) could the information be objectively measured? (2) could risk informed thresholds be developed? (3) did the PI provide a reasonable indication of performance in the cornerstone area? (4) did the PI represent a valid and verifiable indication of performance? (5) would it encourage appropriate licensee and NRC actions? and (6) could the deficiencies represented by adverse trends be recognized and corrected before there was an undue risk to public health and safety? These criteria are well represented in the topical issue paper developed by the IAEA on this topic.

The NRC also faced challenges in 'risk-informing' its PIs. This was done by applying risk insights, where appropriate, to the thresholds. The NRC chose to use performance thresholds in order to provide objectivity and predictability to the oversight process. This approach embodied a number of significant attributes such as: (1) multiple performance levels to allow for observation and assessment of improving or declining trends; (2) thresholds set such that false positives are limited and meaningful differentiation of performance can be obtained; (3) thresholds set at levels that allow for licensee initiatives to be implemented and NRC and licensee diagnostic efforts to take place before reaching escalated regulatory involvement thresholds; and (4) performance thresholds for unacceptable performance set well above the level of unsafe plant operation to allow the NRC and licensee to take appropriate actions without operating in an unsafe condition.

It is important to note that in developing thresholds and selecting the PIs that would be utilized, both the NRC and industry, where appropriate, conducted sensitivity analyses and bench marking studies to validate the risk informed thresholds as well as the PIs themselves. In some instances, PRA data could be directly applied, such as for PIs related to scram data and safety system performance. In other cases, the thresholds were associated with regulatory requirements or the professional judgement of NRC and industry experts. Examples of PIs that used this method to develop thresholds include barrier integrity PIs, which utilize Technical Specification requirements as thresholds, or the availability of physical protection systems, which used expert judgement.

Another key challenge that faced the NRC in its development of PIs was how to collect the data and display it so that the public could easily access and understand the information. It is important to note that licensees are not required by regulation to submit PI information, but instead do so under a voluntary programme. This necessitated that the NRC work closely with industry to develop a process to collect the information. Licensees submit information to the NRC on a quarterly basis as a data stream using e-mail, and then the NRC applies a software program to convert the data stream into graphical displays. After conducting an internal quality assurance (QA) process, these graphical displays are made publicly available on the NRC's ROP web page.

The NRC's ROP web page is designed to provide the user with layers of information, with each succeeding page providing a greater level of detail. The first page, associated with performance assessment information, provides a listing of all the plants alphabetically. Once an individual plant is selected from the ROP performance assessment page, one can then view a display that is organized by cornerstone and which indicates the current band of performance associated with each PI. The NRC developed a colour scheme in the ROP to reflect bands of performance that are related to the significance of an individual inspection finding, as well as the performance level represented by each PI. The ROP has assigned, in ascending order, green, white, yellow and red as the colours that equate with increasing levels of safety significance.

Therefore, each PI on this web page will be shown in the colour that conforms to the current level of performance. From this page, you can then select any individual PI to view its details. This will provide the user with a trend chart showing two year's worth of data, the current status of the PI relative to the thresholds, and the actual data that was submitted by the licensee over the past two years. In addition to the PI information, there is also the capacity to access the inspection related information from the same web page, including the significant findings in each cornerstone and the related inspection reports.

3. SUCCESSFUL RESULTS FROM THE FIRST YEAR OF IMPLEMENTING THE ROP

The data reporting and display of ROP information, especially the PI data, is one of the major successes of the ROP. It has provided a fairly simple and direct method to obtain and make available insightful information about key performance areas of nuclear power plants in a relatively timely manner. It has been cited by a wide variety of both internal and external stakeholders as an excellent communication tool. The NRC has continued to refine the ROP web page based on the feedback it has received.

Another successful aspect of utilizing PIs that emerged during the first year of implementing the ROP is that several PIs provided licensees and the NRC with insights in areas that were not readily observed through our previous process. This particularly applies to areas where there were no pre-existing WANO or AEOD PIs. For example, applying the newly developed PIs for the emergency preparedness and physical protection cornerstones revealed notable, long-standing weaknesses for several licensees that resulted in licensees taking prompt corrective action.

However, the most significant achievement associated with the use of PIs is that the NRC developed and incorporated into its regulatory oversight process an objective, risk informed tool that provides a consistent and understandable basis for evaluating licensee performance. While the PIs currently being utilized in the ROP are not perfect and the implementation of PIs was not without its challenges, as will be discussed below, it is a considerable accomplishment to move so successfully from a theoretical concept to practical application in a relatively short period of time.

4. CHALLENGES ASSOCIATED WITH THE USE OF PIs

It would be great to stop here and focus only on what went well with the PI programme. However, any new, complex programme is subject to implementation issues, and the PI programme is no exception. Perhaps the most significant challenge that emerged was the inherent conflict that materialized as a result of applying generic thresholds to plants that have unique design characteristics. Given the variety in nuclear power plant designs and risk profiles in the USA, it is apparent that several of the PI thresholds may be overly conservative for some plants, and perhaps not conservative enough for others. This issue also was a major factor in both licensees and NRC staff submitting a large number of frequently asked questions (FAQs), which are formal queries received by the NRC about the PI programme. The NRC and industry representatives that participated in an ongoing ROP working group over the past year spent an enormous amount of time trying to understand and resolve these questions. This then led to the constant generation of interim guidance regarding various PIs. This made it difficult for licensees and inspectors to be aware of the most current guidance and contributed to some level of confusion during the past year. Our near term solution to this issue has been to establish a formalized process for addressing questions and making changes to the PI programme. This has been successful in controlling the programme changes. However, a longer term solution will likely be the development of plant specific thresholds for several PIs.

The most notable example of this issue was the safety system unavailability PI. While the PI was based on the similar WANO PI, the NRC modified some of the reporting requirements. Therefore, in addition to the issues related to the generic threshold and plant specific design considerations discussed above, the industry also raised concerns about the different reporting requirements and the inconsistency of this PI's definition of unavailability compared with that of the NRC's maintenance rule. In response to the problems that have manifested themselves in this PI, the NRC has formed a multi-discipline task force, including industry and Institute of Nuclear Power Operations (INPO) representation, to work on improving this PI.

The application of PIs has also heightened our awareness of what are known as "unintended consequences". The issue here is that some licensees may take actions that they would not otherwise take in order to avoid a PI "hit". The industry raised just such a concern regarding the counting of manual scrams as part of the initiating event PIs — i.e. the possibility exists that operators may not take the conservative action to scram the plant if conditions warrant. This concern was the basis for excluding manual scrams from the similar WANO PI years ago. The NRC evaluated this issue over the past year, including pilot testing of an industry proposed replacement PI, and determined that its original PI is still more appropriate, despite the fact that some industry representatives still take issue with this feature of the PI. There have been other PIs where the NRC has observed unintended consequences over this past year, such as the unplanned power change PI. There have been incidences where licensees have waited to reduce power until after the time limit for reporting a power change for this PI (72 hours) expired, or they reduced power to just above the point before it would have to be reported (20% power change). The thresholds for the safety system unavailability PI that was discussed earlier may have prompted some licensees to postpone or cancel preventive maintenance or testing to avoid incurring unavailability time against the PI. We have also noted that some licensees strongly debate issues or conduct extensive analyses in an effort to convince the NRC that an issue does not need to be counted against a PI. Clearly, having a process that has potential regulatory consequences and which can be used to compare performance among plants, results in licensees scrutinizing activities more closely.

One other challenging area associated with the current ROP PIs is barrier integrity PIs. These are intended to provide insights regarding the safety performance of a licensee's reactor coolant system (RCS) and fuel barriers. For the other PIs, the green to white thresholds represent a level of performance at which the NRC should engage licensees on their efforts to understand the underlying root cause of the issue and effect corrective actions. However, the barrier integrity PI thresholds were set at performance levels related to the Technical Specifications for RCS leakage and activity. The current green to white thresholds are set at 50% of the Technical Specification limits. These thresholds are at a level such that a plant would not cross a green to white threshold until it had a substantial leak or fuel failure that would typically warrant a plant shutdown. Thus, while these PIs may contribute to public confidence by providing information on how well the barriers are performing relative to regulatory requirements, they do not provide indications of problems that warrant NRC involvement early enough. We have not yet resolved this issue with industry.

5. FUTURE INITIATIVES

Finally, the NRC has several initiatives associated with the use of PIs that are currently in process or are planned. The NRC's Office of Research has been developing a Risk Based Performance Indicator (RBPI) programme for the last several years that has the potential to enhance our current suite of PIs. Two particular enhancements that may be provided by the RBPIs are the application of plant specific thresholds to safety system PIs and the development of indicators associated with shutdown conditions. These improvements are at least several years away and are contingent upon the ability to develop a common database of plant safety equipment performance information. It is envisioned that such a database could effectively serve the needs of all organizations that need access to plant performance information such as INPO and WANO, as well as the NRC and the licensee. This could potentially accommodate different data collection and reporting needs without overburdening licensees. However, there are several problems that must be addressed before this vision is realized, such as issues with public access to the information and database content and structure. Finally, the NRC has initiated an industry trending programme for the purpose of confirming that the operational safety of nuclear plants is being maintained and to verify the efficacy of the NRC's regulatory processes. Currently, this programme utilizes the PIs developed by AEOD and the Accident Sequence Precursor (ASP) programme maintained by the NRC's Office of Research. The NRC will build on these long standing programmes by utilizing information garnered from the reactor oversight process and operational experience data, such as initiating event studies and periodic analyses of safety system performance. The NRC intends to use this programme to look for adverse trends that may indicate a degradation in overall safety performance warranting NRC attention. While this programme is still in the developmental stage, the NRC intends to make current information available soon on its web site.

6. CONCLUSIONS

In conclusion, the NRC has successfully developed and integrated PIs into the framework of its regulatory oversight process, although not without issues that need to be addressed. This was an effort that was, and continues to be, challenging in both the developmental and implementation phases. However, this initiative has contributed tremendously to the NRC's efforts to meets its goal of creating a more objective, predictable, risk informed, and understandable reactor oversight process. The IAEA topical issue paper associated with this topic lists a number of precautions, as well as criteria and characteristics that should be considered in selecting and using PIs. The NRC's experience strongly reinforces their validity and any regulator that is interested in incorporating PIs into their regulatory oversight process needs to give them due attention.

Lead-in Discussion

SUMMARY OF WORK ON PERFORMANCE INDICATORS AT THE OECD NUCLEAR ENERGY AGENCY

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1. BACKGROUND

In 1998, the Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (OECD NEA) initiated an activity with the objective of advancing the discussion on how to enhance and measure regulatory effectiveness in relation to nuclear installations. One of the outcomes of this activity was to establish a task force to develop *internal (direct)* performance indicators (PIs), which would be used to monitor regulatory efficiency ('do the work right'). This task force has exchanged information on national practices and plans, but has not yet produced any common report.

In parallel, a joint CNRA/CSNI (Committee on the Safety of Nuclear Installations) task force was launched in December 2000 to exchange information and develop *external (indirect) indicators* to measure regulatory effectiveness, i.e. the impact on a licensee's safety performance ('do the right work'). The objective of this joint activity was to compile a summary report on plant PIs currently being used or being tested by regulatory bodies and to prepare a set of common PIs that could be used by regulatory bodies within the OECD NEA. This paper discusses the work performed by the joint CNRA/CSNI task force and the results achieved until now.

2. TASK FORCE WORKING METHOD

The task force consists mainly of regulators who have a PI system in operation or under development. Participating countries are Finland, France, Spain, Sweden, the United Kingdom and the United States of America. The World Association of Nuclear Operators (WANO) was also asked to join the task force to share its wide experience in the use of PIs. The task force had a meeting in which indicators used at different organizations were studied and discussed. These discussions included the experience gained from the use of these indicators in different organizations.

In the meeting, the common indicators were identified by a three step process in which the indicators used by most organizations were compared. These indicators were later assessed as to whether they meet certain criteria, which are necessary for indicators used worldwide. The common indicators must be universally understood, objective and easily obtainable from the available data.

3. RESULTS OF THE STUDY

The study identified seven indicators that are common at most of the organizations that participated in the task force. These were:

— power reductions,
— scrams,
— availability of safety systems,
— fuel integrity,
— reactor coolant system integrity,
— collective radiation exposure,
— significance of events.

These indicators were assessed as to whether they meet the criteria that are necessary for the worldwide use of indicators. With regard to universally understood indicators, it was concluded that in spite of differences in definitions, there was a rather broad consensus on the meaning of each of these indicators. With regard to objectivity, it was concluded that these indicators are not susceptible to manipulation or subjective approaches except the indicator describing the significance of events. The reason is that the definition of 'significance' varies very much even when probabilistic safety assessment (PSA) is used as the main 'significance' measure, mainly due to differences in the scope and depth of PSAs. Due to this fact, the safety significance of events was left out. Based on the discussion during the meeting, it was also confirmed that the data needed to obtain these indicators are already available at all participating organizations.

4. DEFINITIONS OF THE INDICATORS

When the above indicators were studied further, it was noticed that there are differences in the definitions between various organizations. For example, there are differences of what kind and how big power reductions are included in the power reductions indicator. Another typical difference between various organizations was whether to count only automatic or both manual and automatic scrams in the scram indicator. The most universally understood indicator at the moment seems to be the collective radiation exposure. These differences in definitions indicate that if information between interested parties is to be exchanged, some harmonization work will be needed in order to ensure correct interpretation of the results.

5. CONCLUSIONS

The study showed that many regulatory bodies of the OECD countries have experience in developing and using PIs. In several cases, PIs have been collected for a significant period of time and the use of indicators has been gradually improved based on the experience. As in many other areas of nuclear safety regulation, the specificity and size of the indicator set needs to be defined in a manner suitable for the national nuclear programme. However, independent of the size of the set, the experience in countries having used indicators for a longer period has shown that the PIs by themselves provide an indication but not a complete measure of the safety of a nuclear power plant. Futhermore, some indicators are an aggregation of several parameters. This must be carefully considered when trends in indicators are evaluated. Due to differences in definitions, PIs should preferentially be used to compare performance over time. Extreme caution must be used in comparing different plants, especially plants in different countries.

Based on the report presented, CNRA decided that the task force should continue its work. The definitions of the six selected indicators need to be improved in order to make them comparable at different nuclear power plants. Indicators can be reported mutually within the group, but cannot be made publicly available for the time being. The group should also continue the exchange of information on national indicator systems that are generally much wider in scope. Such systems are useful for trending individual plants, but not for international comparison because many indicators are not easily comparable.

Lead-in Discussion

SAFETY PERFORMANCE INDICATORS

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Question 1. Can a threshold be established to compare safety data with risk relevance?

The answer is yes. When we speak about safety, there is risk. When we measure safety, we can measure risk. When we know what is acceptable to safety, we know what is unacceptable to risk. *While a threshold tells us where it is safe, it also tells us where it is unsafe.*

Safety performance indicators (PIs) measure how well we are doing in upgrading safety, or degrading risk. In the determination of thresholds, one should carefully consider the characteristics of national policy, local culture and plant specifics. The aim of setting up thresholds that are applicable worldwide is to reach consensus on the key elements for good safety performance, the three attributes in the IAEA framework, for instance.

A miss is as good as a mile. Utilities and regulators should be mindful that the results of PIs may not always convey the complete story. Therefore, the use of PIs should be integrated with other mechanisms such as the business plan and the organizational culture.

Question 2. Can an international system or 'menu' of safety PIs be used in the framework of the national reports prepared for the Convention on Nuclear Safety?

Why would this be necessary? As an industry, it is the responsibility of both regulators and utilities to ensure safety and profitability. How do we tell whether we are good or bad? Performance measurement determines the effectiveness of a utility or the industry when it is done on a nationwide basis. Performance measurement tells how well a utility is meeting its mission, vision and goals. Therefore, the most convincing way to show performance in the national reports might be to provide quantitative figures for a set of commonly agreed indicators.

How to proceed? First, a limited number of indicators should be chosen from the framework of three attributes. Then, a 'menu' should be agreed among the utilities and regulators. Finally, to document the definitions, the criteria and the frequency of their measurement should be issued in the publications of the IAEA.

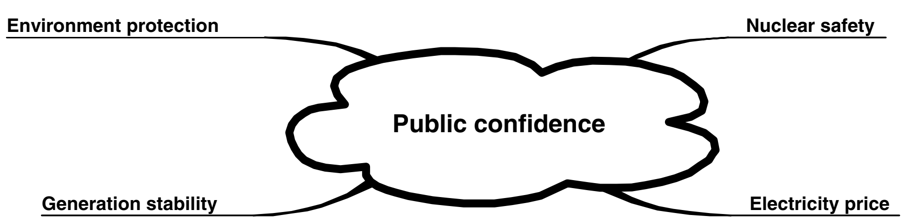
When must care be exercised? Not all people know about nuclear technology, so the indicators selected should not only represent the overview of the utility or industry, but also be easy to understand, even for laymen. Moreover, performance measures will not tell the whole story: good results do not necessarily point to good execution. They represent approximations of the actual system and they do not ensure compliance with laws and regulations. Sometimes the cause and effect of outcomes are not easily established. The 'menu' of safety PIs should not be used alone: they should be supplemented with qualitative justifications, as appropriate.

Question 3. Should the set of internationally agreed safety PIs be used for public information?

By opening your heart you become accepted, by clearing your vision you become clear. We need the confidence of the public because the voice of the public could have a strong influence on the development of the nuclear power industry. We need to deliver our confidence to the public because we want our industry to grow. What does the public want to know from the utilities and the regulators? Analysing the attributes of public confidence will aid in the selection of indicators. What makes this process difficult is the complexity of society and the overwhelming power of the mass media.

Only a set of safety PIs can show to the public, in an objective manner and with reasonable transparency, that nuclear power operations are safe. This would help to create a 'win-win' situation for everyone and push the development of the nuclear power industry.

Finally, coming together is a beginning, keeping together is progress and working together is success.



Lead-in Discussion

SOME THOUGHTS ON SAFETY PERFORMANCE INDICATORS

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Topical Issue Paper No. 5 on Safety Performance Indicators raised three questions about these indicators for discussion in this session. In this short paper, some thoughts are presented as a response to those questions.

Question 1. Can a threshold be established to compare safety data with risk relevance?

One of the basic criteria for safety performance indicators (PIs) is that they have to be directly related to safety. When we select an indicator for the PI programme, we have to analyse whether it fulfils this required characteristic. Of course, the term ‘direct relationship’ is not well defined, and the scope of different indicators can be different. The analysis can and should be done using both deterministic and probabilistic approaches. The deterministic approach can help to decide whether the candidate indicator has a relationship to safety at all. The probabilistic approach can help to determine how ‘directly’ the indicator is related to safety. For this analysis, a probabilistic safety assessment (PSA) model can be used. Looking at the proposed set of safety PIs, however, one can see that quite a few of the indicators are such that they cannot be directly analysed using probabilistic models. In other words, their value cannot easily be converted into so called basic events for fault trees. The risk relevance of these indicators should be analysed by other methods. Once an indicator system is established and specific indicators are selected, the risk significance has to be determined in order to calculate possible weighting factors to calculate the values of higher level indicators or to establish thresholds.

The definition of thresholds can easily be done if one can define a direct function between the indicator value and the risk value. On the basis of the tolerable risk increment, the threshold of the different bands for the indicators can be calculated. However, in some cases the risk values cannot directly be expressed as a function of the selected indicator. This applies, for example, to most of the indicators in the third attribute of the IAEA's proposed framework (plant operates with a positive safety attitude). It could be rather difficult to quantify the relationship between the number of temporary modifications, or the number of quality assurance (QA) audits and the core damage frequency or radioactive releases.

The other factors that should be taken into account when defining thresholds are management and financing considerations. The threshold may depend on what resources are needed in order to keep the concerned indicators below a proposed threshold, or within a selected band. The reasonable values for threshold or band limits should, finally, be adjusted by the management on the basis of financial factors. But, of course, the safety limits cannot be compromised by economics.

Question 2. Can an international system or 'menu' of safety PIs be used in the framework of the national reports prepared for the Convention on Nuclear Safety?

The objectives of the Convention on Nuclear Safety are to: achieve and maintain a high level of nuclear safety worldwide; establish and maintain effective defences in nuclear installations against potential radiological hazards; and prevent accidents with radiological consequences, and mitigate such consequences should they occur.

In order to analyse whether Member States meet the objectives of the Convention, a periodic report is prepared by the countries and reviewed by a conference. This is a kind of safety assessment report with a very wide scope. When preparing the reports, most countries use PIs as a means of safety assessment.

The current scope of the review covers a very wide range of questions to be addressed regarding the objectives of the Convention. These questions include legislation and regulation, general safety considerations (including financial and human resources, QA, radiation protection, etc.) and the safety of installations (siting, design and construction, and operation). Obviously, PIs can only be used for the analysis of some of the areas in the reports. Currently, countries use some PIs for the assessment of the safety of operations. These indicators are selected by the authors of the reports and they are not suitable for international comparison. The question that is posed is whether the Review Conference on the Convention on Nuclear Safety is a forum for international comparison. Many countries would probably not agree with this. Safety indicators, however, can be used to demonstrate how well the safety of the nuclear installation is maintained by comparing the indicator values to limits, thresholds or goals set by the utility or the country. If we want to use an international set of indicators for such a purpose, a set of indicators has to be established first and accepted by the potential users.

Question 3. Should the set of internationally agreed safety PIs be used for public information?

The promotion of the use of nuclear energy is the way to save nuclear energy. Nuclear installations are always in the focus of the public. We have to convince the public that nuclear energy is safe. We have to do this because we are convinced that it is safe, not because we want to save our jobs. It is very important that the method we use to inform the public is objective. We must not cheat the public. Any nuclear organization will lose its credibility as soon as it lies to the public. Therefore, the use of safety indicators as objective measures for public information is very important and probably every country does so. The question is: what indicators should be used? Indicators used for public information can be significantly different from those commonly used for safety evaluation. The indicators selected should be meaningful for the public. For example, the chemistry index would not say anything for most of the members of the public. They are more concerned about the environmental impact, radioactive wastes, etc. On the other hand, the interest of the public may change from time to time. Political influence can also change the interest of the population.

A set of possible international indicators to be used can be determined. Nonetheless, the suitability of the indicators depends very much on cultural factors present in each country. Thus, the international system can serve as a ‘menu’ for users at the national level.

ANOTHER VIEW AT MANAGING RISKS

(Session 6)

Chairperson

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RISK MANAGEMENT IN THE CHEMICAL INDUSTRY

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Abstract

RISK MANAGEMENT IN THE CHEMICAL INDUSTRY.

The beginning of the twenty-first century has seen the emergence of major trends, such as heightened awareness of health, safety and environmental topics, increasing involvement of the general public in such issues, and the development of new means and forms of communication. With the satisfaction of basic needs in the industrialized world, and the collapse of traditional ideologies, this growing awareness has become a major factor influencing sociology, politics, law and economics. Society asks — and is entitled — to know more about the risks to which it is exposed. In the case of the chemical industry, this refers to the substances it manufactures, which are highly beneficial to society, but also pose risks to humans and the environment, both in the form of emissions and as part of professional or consumer products. The paper will explore the recent trends and challenges concerning the management of chemicals and the main risks they pose, and will outline the chemical industry's commitment to the safe management of its chemicals.

1. ENVIRONMENT, HEALTH AND SAFETY IMPACTS

Chemicals are used to make virtually every human made product, and play an important role in the everyday life of people around the world. Such products provide protection for crops and increase yields, prevent and cure disease, provide insulation to reduce energy use and provide countless other benefits that make life better for people.

While the chemical industry made good progress in reducing the overall environmental footprint, over the entire life of a chemical product (‘from cradle to grave’) the potential for negative impacts on humans and the environment remains. This impact results from the use of non-renewable resources, the emission of chemicals in the environment, and also the negative impact of chemicals contained in products and waste. Most recently, concern has been expressed about chemicals which interfere with the normal function of the hormonal systems of humans and animals (i.e. endocrine disrupters) and substances which impact on children’s health.

2. CHEMICALS MANAGEMENT AND THE OPTIMIZATION OF THE USE OF CHEMICALS

International and regional legal instruments have been adopted relating to chemicals and consumer protection, occupational health, environmental protection, process and transport safety, and substance management. These rules, together with those at the national level, constitute the legal basis of chemicals management.

However, independent of government regulations, the global chemical industry considers the protection of human health and the environment a fundamental concern. Through the 'Responsible Care' programme, the chemical industry is committed to continuously improving all areas of chemicals management — production, occupational health and health care, process and transport safety, product use and waste disposal. Indicators of performance are published annually by the majority of members of the International Council of Chemical Associations (ICCA).

We have reduced our emissions dramatically through a combination of voluntary measures and regulations. Public agency reports indicate that the air and water quality has improved substantially. The chemical industry remains committed to continuously improving its performance.

In prioritizing substances for assessment and control, a common approach is to focus on those which are persistent, bio-accumulative and toxic. It needs to be recognized, however, that persistence and bio-accumulation of substances are, in themselves, not necessarily problematic. Indeed, the longevity of products may be desirable in certain applications. However, the presence of these properties should trigger the immediate review of their toxic and eco-toxic properties.

Carcinogenic, mutagenic and reprotoxic effects are undesirable chemical properties. However, substances with such intrinsic properties can have important uses and are frequently the basic chemicals for the manufacture of products such as pharmaceuticals. Emissions of these substances resulting from production should be minimized.

The chemical industry wants to maximize the benefits of its products to society while affording proper protection. It cannot accept the general demand to minimize or ban the use of chemicals on the basis of their intrinsic properties. This demand is not consistent with sustainability targets.

Technological development is a key driving force towards sustainable development. Experience has shown that every new process and product generation leads to a substantial decline in materials and energy input, and thus relieves the burden on the environment.

3. RISK ASSESSMENT AS A FUNDAMENTAL ELEMENT OF RISK MANAGEMENT

The chemical industry aims to market globally only those products that can be manufactured, used and disposed of safely. If we fail to do so, the very benefits that we offer to society would be jeopardized and our long term economic success would be threatened.

Meeting this safety objective requires a range of assessments which take into account the use of the chemical, the exposure, its intrinsic hazards, and its possible effects on human health and the environment. The risks are determined by assessing the hazards with the exposure during all critical phases of the chemical's life cycle.

Initially, risks are characterized by comparing exposure and effect. If the level of exposure is incompatible with human health and the environment — here safety factors are taken into account — a risk may result, requiring risk reduction measures (risk management).

Risk assessment is the key principle of chemicals management, although its implementation lags far behind the expectations of all stakeholders. This inertia is caused primarily by procedural problems. However, procedures can be streamlined.

An initial risk assessment of all the areas of the whole life cycle needs to be performed to identify those requiring an in-depth targeted assessment. There is also a possibility that the exposure profile or intrinsic properties of a chemical may be of concern only in specific uses, to specific groups of the population and when released into specific parts of the environment. In this case, a targeted risk assessment procedure is also appropriate.

Agreed upon risk assessment procedures and guidelines for new and existing chemicals are an indispensable tool for the chemical industry and governments to decide whether or not risk reduction measures have to be taken.

4. AVAILABILITY OF DATA

Sound, scientifically derived data are essential to risk assessment and these data must be made available. Large amounts of data have already been produced, e.g. the data and information on chemicals provided by the chemical industry to the OECD HPV Screening Information Data Set (SIDS) programme, which was established in 1989.

Existing chemicals data have also been gathered and reviewed for about 10–15 years in international governmental organizations such as the International Programme on Chemical Safety (IPCS) and the International Register for Potentially Toxic Chemicals (IRPTC-UNEP).

4.1. The ICCA HPV chemicals initiative

The global chemical industry has launched its own initiative to generate additional information to help satisfy public expectations. In particular, we will provide more extensive and reliable data for hazard and risk assessment.

By spreading the effort across the entire chemical industry, the ICCA is co-ordinating and accelerating the process of data collection and initial hazard assessment for 1000 high production volume (HPV) chemicals. Other chemicals will then follow. These chemicals make up over 90% of the world's chemical production and have a greater potential for exposure to human and the environment. The industry is committed to ensuring that all data gaps in the OECD standard SIDS for these chemicals will be filled in by the end of the year 2004.

The ICCA HPV contribution to the OECD programme will help to improve the basis for setting priorities in accordance with international and regional regulations. In addition, it will speed up the process of risk assessment and management, and will also provide a basis for speeding up the process for the classification and labelling of chemicals.

A high production volume has been selected as the criterion for substance assessments and covers chemicals produced in quantities >1000 t/a in more than one region. Those substances with production volumes under 1000 t/a that are considered to have a special relevance to human health and the environment are included or can be included as being of priority in the ICCA review programme.

The information gathered will lead to an improved prioritization process for further work. It also offers a firm basis for starting risk assessment.

4.2. Long range research initiative

The global chemical industry has also set up a Long-range Research Initiative (LRI) to address the existing and emerging health and environmental issues facing the chemical industry. It provides financial support for external research to focus on the development of a sound scientific understanding of the impact of chemicals on people and the environment. It is intended to:

— provide new insights into risk assessment;
— generate information for sound and cost effective regulations on chemicals.

The emphasis of the research programme for the next six to ten years includes:

— endocrine disruption;
— assessment of exposure for humans and the environment;

— development of methods for risk assessments, in particular with respect to the marine environment;
— improvement of the understanding of the dynamics of the ecosystem;
— carcinogenicity, immunotoxicity, allergy and neurotoxicity.

4.3. Product stewardship

Product stewardship is the responsible and ethical management of the health, safety and environmental aspects of a product throughout its total life cycle. Key elements of product stewardship are:

— The continuing development of product stewardship management systems.
— The definition of good practices and development of relevant indicators of performance.
— Improved member and customer support, particularly for small and medium sized enterprises. This is especially important in the further development of product stewardship within the Responsible Care programme, to demonstrate that industry is playing an active role in managing the risks associated with chemicals. This work will be done partly through the ICCA, and partly at the regional and national levels.

5. CONCLUSION

The chemical industry recognizes its responsibilities in ensuring that the chemicals it places on the market are safe. Much has been done to meet these objectives, and much will continue to be done, in collaboration with international authorities, and the other parties involved.

EVALUATION OF RISK FROM A PROPERTY INSURANCE PERSPECTIVE

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Abstract

EVALUATION OF RISK FROM A PROPERTY INSURANCE PERSPECTIVE.

Discussions on risk associated with nuclear power facilities usually focus on the nuclear safety risk and the potential public health and safety consequences of a nuclear accident. In addition to the on-site consequences of a nuclear event, insurance companies providing property damage coverage for nuclear power plants must evaluate risks associated with other lesser magnitude, but potentially very significant, events. The paper discusses some of the traditional methods of assessing insurance risk, reviews some of the methods being considered to better quantify insurance risk in the future, and summarizes a few of the more significant historical property damage insurance claims.

1. INTRODUCTION

When the issue of nuclear power plant risk is discussed, most people immediately think of the potentially catastrophic effects of an event causing damage to the nuclear fuel, resulting in the release of significant amounts of radioactive contamination outside of the plant's containment. The considerable costs associated with the on-site consequences of a core damaging event requiring extensive decontamination, clean-up, debris removal and disposal, and site restoration would certainly be covered by a typical property insurance policy. From a severity standpoint, a core damage event would most likely result in a maximum payout. Insurance payments would probably total the limits specified in the insurance contract, regardless of whether or not the containment was breached or any radioactive contamination was transported off the nuclear plant site. However, the likelihood of such events occurring is extremely remote. Nuclear power plants are large, complex industrial facilities that contain numerous high value pieces of equipment, many of which are totally separate from the primary or nuclear portion of the plant. The more probable risk of loss to the property insurance company involves failure of such equipment that could result in tens of millions of dollars in damage and very long plant outages.

Typical property insurance policies cover the repair or replacement costs associated with damages resulting from an accident. Some programmes also provide payments to cover a portion of the business interruption costs associated with the loss of generation due to plant outages that result from equipment damage due to an accident. From the property insurance perspective, 'accidents' are not limited to nuclear events, but rather apply to any unforeseen or unexpected event that causes damage to plant property or equipment. Most property insurance policies contain exclusions for damage that occurs gradually. Damage such as erosion, corrosion, various forms of cracking including stress corrosion cracking and fatigue cracking, and the gradual accumulation of radioactive contamination all occur over time, and are typically not covered by a property insurance policy.

2. INSURANCE RISK EVALUATION

Over the past 10–15 years, sophisticated analysis tools have been developed to estimate the probability of core damaging events occurring and the consequences of such events. In most areas of the world, probabilistic risk assessments (PRAs) are routinely being used to estimate the probability of core damage events, and to identify particular vulnerabilities in individual plant designs. Both the plant operators and government regulatory agencies use these analyses to monitor the nuclear safety risk and to identify opportunities to further reduce the possibility of a nuclear accident. Property insurance carriers typically do not conduct independent evaluations of nuclear safety issues, but rather rely on the work done by other agencies such as government regulators, the International Atomic Energy Agency, the World Association of Nuclear Operators (WANO), and the Institute of Nuclear Power Operations (INPO) to ensure that the nuclear safety risk is minimized.

Most insurance company risk evaluation efforts focus on non-nuclear or balance-of-plant (BOP) issues. While BOP equipment failures could initiate a sequence of events culminating in damage to the nuclear fuel, the probability of such a scenario is extremely remote. The more likely insurance risks involve damage resulting from failures of plant equipment. Such events typically do not challenge nuclear safety, but they can be financially significant, both in terms of the physical damage and the impact of an extended plant outage. In an effort to reduce the risk of unexpected events causing damage to plant structures and equipment, most property insurance companies have adopted certain standards or technical requirements that insured facilities are expected to meet. These standards have traditionally been deterministic in nature, and are typically based on historical experience. While the loss experience in the nuclear power industry is somewhat limited, the conventional side of a nuclear power facility differs very little from a fossil fuelled power plant, and considerably more historical experience is available.

Property insurance loss control standards typically address two general areas. The first area relates to property and fire protection issues. Standards in this area specify requirements pertaining to fire protection water supplies, building construction features and materials, fire barriers to separate certain plant areas and equipment, fire suppression systems protecting combustible hazards, and administrative programmes addressing such issues as the control of transient combustibles, impairments to fire protection systems, and fire response team organization and training. Other requirements in the property and fire protection area address protection of buildings and equipment from the effects of natural events. While primary plant buildings and equipment are designed to withstand the effects of earthquakes, windstorms, lightning and floods, other plant buildings such as warehouses, administration buildings and other ancillary structures may not be constructed or protected to the same standards. Damage to these structures due to a natural event could result in a very significant financial loss.

The second area usually covered by insurance loss control standards pertains to machinery breakdown issues. These requirements address the operation, inspection, and maintenance of major plant equipment such as the turbine generator, large pumps, motors and other rotating equipment, transformers, and diesel generators. These standards specify the required scope and frequency of certain inspection and maintenance activities associated with this equipment.

The verification of compliance with insurance company loss control requirements is usually carried out through periodic on-site plant evaluations. Representatives of the insurance company visit insured plants at specified intervals to assess continuing compliance with the standards. These plant evaluations typically include a tour of most radiologically accessible buildings and areas to assess conditions and to identify significant changes, a review of the status and readiness of fire protection systems, a practice drill involving the fire response team, a review of major equipment maintenance records and inspection reports, and discussions with senior plant management. Non-compliance with loss control requirements could result in adjustments to the insurance premium or limitations on insurance coverage for certain pieces of equipment or areas of the plant.

As noted above, insurance company loss control requirements have historically been deterministic. For example, certain equipment inspections are required to be carried out at specified intervals regardless of how well the equipment has been performing. Other requirements are based on expert judgment of the perceived risk rather than on a thorough analysis of the actual risk. Up until recently, historical experience and expert judgment were really the only bases on which to establish such requirements. However, the probabilistic tools and methods being used to assess the nuclear safety risk are slowly finding their way into non-nuclear-safety applications. Performance based and risk based approaches are beginning to be used in many areas of plant operation and equipment maintenance. It is only a matter of time before property insurance companies start to use these tools to refine their loss control requirements and prioritize loss control activities based on quantifiable risk estimates.

3. SIGNIFICANT NON-NUCLEAR PROPERTY DAMAGE EVENTS AT NUCLEAR POWER FACILITIES

Over the past 12–15 years, there have been numerous events at nuclear power plants around the world that resulted in significant property damage, but have not involved the primary or nuclear portions of the facility. Listed below are several examples:

- *February 2001.* One unit at this two unit PWR facility was at 39% power and increasing at 3% per hour following a just completed refuelling outage when a circuit breaker fault caused a fire in the breaker cabinet, a partial loss of AC off-site power and a reactor shutdown. The failure of a DC breaker to function properly resulted in unavailability of the main turbine emergency lubricating oil system, causing the turbine generator to coast down without lubrication. Extensive damage to the turbine generator resulted in an outage of approximately 17 weeks and an insurance claim of approximately $60 million.
- *December 1993.* This single unit BWR was operating at 93% rated power when a low pressure turbine blade failed. One blade segment pierced the turbine casing and came to rest approximately 23 m from the point of ejection. Excessive vibration resulted in hydrogen being released from the generator seals, causing several small fires. Turbine generator lubricating oil lines were also ruptured, causing fires in the under turbine areas. Several other turbine blades broke off and penetrated the condenser, allowing lake water to enter the turbine building. Approximately 3 700 000 L of water and 64 000 L of lubricating oil collected in the lower elevation of the turbine building. Another 1 900 000 L of the oil/water mixture collected in the radwaste building. Significant damage was caused to the turbine generator and exciter, requiring extensive repairs. In addition, 5000 condenser tubes needed to be replaced. The unit was out of service for approximately one year, resulting in a total insurance claim of $183 million.
- *August 1992.* The eye of a Category 4 hurricane with sustained winds of 230 km/h and gusts estimated at 320 km/h passed directly over this two unit PWR plant that also has two oil fired fossil units on the site. Although the storm caused extensive damage to many buildings, including the fossil units, the two nuclear units sustained relatively little damage. Both nuclear units returned to service within approximately three months; however, the units remained down for an extended period for reasons other than damage caused by the storm.

The insurance claim totalled $144 million, with $80 million associated with the destruction of the plant's central receiving warehouse alone.

— *November 1991.* This unit at a two unit PWR plant was operating at 100% power when plant operators initiated a routine test to verify the operability of the automatic trip devices in the turbine auto-stop oil system. During the test, a momentary drop in oil pressure in the auto-stop oil system initiated a sequence of events and equipment failures that resulted in a turbine overspeed condition. Several low pressure turbine blades separated from the rotor disc, and at least one penetrated and exited the turbine casing. Excessive vibration caused the generator hydrogen seals to fail and the lubricating oil lines to rupture, resulting in fires on the turbine operating floor and on the levels below the turbine generator. Extensive damage was sustained to the turbine generator and associated equipment. The unit was out of service for approximately five months, resulting in a total insurance claim of $89 million.

— *October 1989.* Turbine vibration at this single unit gas cooled reactor plant led to the rupture of a lubricating oil line at a turbine bearing, followed by a hydrogen explosion and an oil fire. The emergency cooling system was rendered inoperable by the fire; however, plant operators were eventually able to bring the unit to a safe shutdown condition. Water flooded the turbine and reactor buildings when fire burned through a rubber seal in the condenser. The turbine building and associated equipment sustained extensive damage from the fire that took four hours to bring under control and six hours to extinguish. The unit was permanently shut down following this accident, and property damage totalled approximately $95 million.

4. CONCLUSION

The vast majority of property insurance claims at nuclear power facilities involve damage to conventional or non-nuclear equipment in the plant. While an accident involving significant damage to the nuclear fuel would result in maximum payments under a property insurance policy, the probability of such an event occurring is considered to be sufficiently remote that most insurance carriers focus their risk evaluation and loss prevention activities on the lower severity, but higher frequency events. As has been demonstrated historically, non-nuclear events at nuclear power facilities can have potentially catastrophic consequences. Nuclear safety must continue to be the principal focus for nuclear plant operators; however, plant reliability and long term economic viability also hinge on minimizing the risk of major non-nuclear equipment damage events and associated long duration outages.

PANEL

MAINTAINING COMPETENCE

Chairperson: **J. Watterson** (South Africa)

Members: **M. Fujitomi** (Japan)
J. Gutteridge (United States of America)
L. Hahn (Germany)
J.L. Head (United Kingdom)
O. Mykolaichuk (Ukraine)
A. Stritar (Slovenia)

Panel Statement

THE SOUTH AFRICAN EXPERIENCE

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1. INTRODUCTION

It is interesting to examine how the need to develop and maintain skills in nuclear safety (and also radiation protection) was dealt with in South Africa. Although the country had a highly distorted political and social system at the time, some insight can be derived from this experience.

The original nuclear power programme in South Africa was started in the mid-1960s and resulted in the construction of two PWR reactors at Koeberg, near Cape Town, in the extreme south of the country. These were built by the French company Framatome, and account for some 5% of South Africa's installed electrical generating capacity of about 40 GW.

2. INTERNATIONAL MOBILITY OF TRAINED PROFESSIONALS

In order to establish a pool of competency within the country, South Africa relied initially on the international mobility of professional individuals with education, training and experience, i.e. competence, in the fields of nuclear safety and radiation protection. It did this essentially by attracting them in an open market situation. In other words, incentives were provided to attract professionals with the necessary skills to the country and the programme. Considerable reliance was placed on the willingness of professionals to move to the country and on the ability to provide the necessary incentives. The programme therefore initially depended, and for many years relied, on the international *mobility of nuclear safety professionals* (as well as other professionals in the nuclear field).

Many of these professionals were short term consultants, but many of them stayed permanently, forming a pool of professionals with a high degree of competence and motivation. These professionals were (and still are) employed by the South African regulatory authority and by the power utility company Eskom.

3. USE OF TRAINING PROGRAMMES IN COUNTRIES WITH ESTABLISHED COMPETENCE

One way that was used to augment and maintain the pool of trained professionals was to send individuals to other countries for education and training in specific areas. In this regard, a great deal of use was made of courses run by the National Radiological Protection Board (NRPB) in the United Kingdom. This represents an example of the use of existing *training programmes in a country with an established competence.* Many of the longer courses in this series are no longer offered by the NRPB. However, institutions such as the INSTN at Saclay, in France, offer this option.

4. DEVELOPMENT OF A LOCAL CAPABILITY IN EDUCATION AND TRAINING

A second method that was used to increase the skills base, primarily at a more practical level, was the development of local training centres and programmes. A comprehensive training programme for reactor operators, radiation protection officers and other professionals at this level was put in place by Eskom. This has resulted in the development of an on-site training centre with a high degree of competence and training skills. It operates many different courses for on the job training. Most of this education has taken place outside of the main stream of tertiary education within South Africa, i.e. the universities and technical colleges (‘technikons’).

5. RECENT DEVELOPMENTS

Recently, major developments have taken place in South Africa. Thanks to an initiative by the IAEA, a regional centre has been established at the University of the Witwatersrand. This centre provides a course for post-graduate study in the field of radiation protection. It leads to a post-graduate diploma in this field. It also provides the courses for a Master of Science (M.Sc.) degree in radiation protection by course work and research report. This is the first time that existing tertiary educational institutions in South Africa have been directly involved in education in radiation protection and nuclear safety, leading to a specific qualification in this field. The syllabus is based on the IAEA standard syllabus for post-graduate education in radiation protection.

The idea that was developed here as a result of the IAEA initiative is the establishment of a regional centre with the responsibility for post-graduate education in Anglophone Africa. This is a very important idea when seen in the light of the need for the education and training programmes to be viable both as regards the standard of the education and, of equal importance, economic sustainability. Such a regional centre has existed in Argentina for many years and has provided an important focus of education and training in Latin America.

This year this initiative has been extended in South Africa to provide a post-graduate university course on the physics, engineering and safety of nuclear power reactors. This course has been developed in close co-operation with the nuclear industry and the nuclear regulator. It also leads to a post-graduate diploma and can be augmented with a research report to lead to an M.Sc. degree. This course could also be offered on a regional basis with the assistance of the IAEA.

The primary motivation for this initiative has been a revival of the nuclear power industry in this country because of the development of the pebble bed modular reactor (PBMR) concept and its possible commercialization.

The University of the North-West in South Africa has established an M.Sc. degree in applied nuclear science and technology. This is designed to provide post-graduate education in general in a number of areas of nuclear science and technology. This initiative has already had a marked effect in adding to a pool of competent individuals with skills in this field.

6. CONCLUSION

In South Africa the initial phase of reliance on the international mobility of nuclear safety professionals was augmented by education and training at institutions in countries with established nuclear programmes. On the job training provided an important component in the development and maintenance of competence. Only recently has this been augmented by the development of programmes involving tertiary educational institutions in education in these fields.

Perhaps the following three conclusions arise from a consideration of this experience.

— The international mobility of professionals can be of great value. Another consideration here is that the profession could become more attractive to young people if such international career paths are perceived to exist.
— The existence of centres for the education of professionals in this field in countries with a developed nuclear industry is of great value. This is already

part of the IAEA strategy. Ways of ensuring that such centres are economically viable should be examined.

— The development of new and existing regional centres is an initiative that has been supported by the IAEA in the radiation protection field. It is a way of providing education at a high level that can also be viable economically and in terms of student numbers.

Panel Statement

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Competence can be defined as the knowledge and skills of all persons and organizations engaged with a specific matter. The contributors to maintaining and developing competence in nuclear safety are: education and training of personnel; management of knowledge; research and development; evaluation; and exchange of experience. Necessary for maintaining and developing competence are adequate personnel resources, specific organizational structures, sufficient material and economic resources, an adequate technical and scientific infrastructure and a favourable political and social climate. A high level of competence requires that all of the elements described above are fully developed. Deficiencies in even one element have the potential for lowering competence. In the case of deficiencies in more than one element, a severe reduction of competence must be considered. In many countries the potential loss of competence in nuclear safety is a major concern due to uncertainties about the future of nuclear power, the ageing of the work force, reduced educational opportunities in the field of nuclear engineering and the consequential lack of interest of new professionals to engage in the nuclear field. It is widely agreed that specific measures are necessary to avoid loss of competence.

Maintaining competence in nuclear safety is a duty and responsibility of the individual countries. In some fields the IAEA can provide important and excellent support. One example is training and education. In the area of nuclear safety, training opportunities have been offered by the IAEA to professionals from Member States over the past many years. These activities are an important contribution towards fulfilling the educational and training needs of Member States. The focus has been in the main areas related to the safety of design and operation of nuclear power plants and research reactors, safety assessment methods and tools, and regulatory control. Training courses and specialized workshops in the above mentioned areas have been offered in English, French, Russian and Spanish as part of interregional, regional and national IAEA activities. Most commonly, training activities are implemented in the framework of technical co-operation projects and extrabudgetary (nuclear safety) programmes. In September 2000, the IAEA General Conference referred to its earlier resolutions and stressed the special importance of education and training in radiation protection, nuclear safety and waste management; it urged the IAEA Secretariat to strengthen, within available financial resources, its current efforts in this area and, in particular, to assist Member States at regional and national training centres that would arrange for such education and training to be conducted in the relevant official languages of the IAEA. In response to this resolution, the IAEA convened an Advisory Group meeting in Vienna from 27 to 29 March 2001 to review the efforts to date and to advise on the overall strategy, structure, scope and means of implementation of an IAEA programme of education and training in nuclear safety.

The main result of this meeting was that the Advisory Group proposed an integrated strategy for education and training in nuclear safety which recognizes that there is a need for a long term, sustainable programme of education and training in nuclear safety in Member States and that a gap exists between the nuclear safety knowledge required in Member States, and the capabilities of the IAEA to deliver training. Therefore, complementary to its training courses, the IAEA needs to concentrate its efforts on assisting Member States to establish national sustainable education and training programmes that are in line with international safety standards. An essential element of this effort is the development by the IAEA of model type training leading to a 'train the trainers' situation that will ultimately help implement the national programmes in a harmonized way.

In addition to the important matter of education and training, it must be pointed out that maintaining competence needs more effort than just excellent training programmes. One key element is generally an intelligent use of the accumulated knowledge through good knowledge management. However, the main task in developing appropriate measures for maintaining competence in nuclear safety is to carry out a thorough analysis of the reasons for the possible loss of competence. These reasons must be carefully examined and fully understood before a successful concept for maintaining competence can be established in the individual countries.

Panel Statement

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The invitation to take part in this panel discussion included a request for an introductory statement from each panel member expressing his or her personal views on the issue of maintaining nuclear safety competencies. As noted in the conference programme, I was recently a member of a task group set up by the Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (OECD NEA) to make specific, practicable proposals to ensure the maintenance of essential nuclear safety competencies. This statement draws on the task group's report C [1], which was endorsed by all members of the study group and so represents not only my views but those of the other members of the group.

The background to the CNRA's decision to set up the study group will be familiar to most persons attending this conference. In many countries with nuclear power programmes, the age profile of staff in the regulatory bodies and in the operating organizations is such that a high proportion of experienced staff will retire over the coming decade or so, with the potential loss of the nuclear safety knowledge base. Over the last decade, many university courses in nuclear science and engineering have been closed for lack of students. The faculty members teaching the remaining courses are not getting any younger and many of the facilities available to support the courses are outdated. Consequently, the numbers of graduates, particularly at the bachelor level, with relevant qualifications to fill the vacancies left by retirements are declining. The situation is well exemplified by two recent reports, one based on a survey covering 16 OECD Member Countries and published by the OECD NEA [2] and one based on a survey of the supply of and demand for graduates in nuclear science and engineering in the USA carried out by the US Nuclear Engineering Department Heads Organization (NEDHO) [3]. There are exceptions to the general pattern. It is not surprising that countries with ongoing nuclear power construction programmes, such as France, Japan and the Republic of Korea, are not experiencing the decline in the numbers of courses and graduates in the relevant disciplines.

In response to concerns brought into sharp focus by the reports referenced above, the CNRA, in conjunction with the Hungarian Atomic Energy Authority, organized a workshop in Budapest in October 1999, which was attended by representatives from 13 countries and two international organizations, the IAEA and the OECD NEA. At the workshop, papers were presented on a range of relevant topics, including the identification of the competencies and facilities considered essential to ongoing nuclear safety and the initiatives already taken in member countries to assure the retention of essential competencies and facilities. The workshop report made a number of recommendations for the implementation of which the CNRA might act as a catalyst. The CNRA task group was established to bring forward specific practicable proposals to implement the recommendations. The task group's report [1] contained nine recommendations, some of which I paraphrase in this introductory statement.

The task group noted that signatories to the Convention on Nuclear Safety have an obligation to address these issues and cannot leave the provision of suitably qualified and experienced staff for nuclear facilities and regulatory bodies entirely to the workings of market forces. One of the recommendations was that the CNRA should urge governments to take a lead, either directly or through appropriate agencies, in the immediate designation or setting up of national committees, comprising regulators, operators and educators, to identify essential education and training facilities and take whatever action is needed to ensure their ongoing viability. I am pleased to be able to report that in the United Kingdom, such a committee has been established as a joint initiative by the Department of Trade and Industry (DTI), which is the department accountable to Parliament for nuclear safety, and the Nuclear Installations Inspectorate (NII), the regulator.

The task group noted the work done by the IAEA on the development of a generic competency framework for a regulatory body, which it commended to the CNRA as a starting point for the development of appropriate competency frameworks for national regulatory bodies. The task group recommended that the CNRA should encourage the development of a generic competency framework for a nuclear power plant operator.

The task group noted many examples of good practices in the development of competency profiles, in the maintenance of the essential nuclear safety knowledge base and in national and international co-operation in the provision of education and training. Examples of good practices are included in the task group's report [1]. The task group recommended that these examples be brought to the attention of the proposed national committees for consideration of their applicability in their countries.

Two more recommendations I shall briefly mention are that the Young Generation Network (YGN) of the European Nuclear Society, or similar body outside Europe, should be involved in the work of the national committees, and that the CNRA should set up a subgroup of its own membership to organize workshops similar to the Budapest workshop as a means of monitoring new developments and emerging issues over the coming years.

REFERENCES

[1] OECD NUCLEAR ENERGY AGENCY, Assuring Future Nuclear Safety Competencies: Specific Actions, OECD, Paris (2001).

[2] OECD NUCLEAR ENERGY AGENCY, Nuclear Education and Training: Cause for Concern? OECD, Paris (2000).

[3] NUCLEAR ENGINEERING DEPARTMENT HEADS ORGANIZATION, Manpower Supply and Demand in the Nuclear Industry, NEDHO, Washington, DC (1999).

Panel Statement

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After I was invited to attend this panel and asked to prepare the initial statement, my first idea was to speak about the importance of public acceptance of nuclear technologies. There is no doubt public acceptance is one of the most important problems that we nuclear professionals are faced with. That is why fewer young people are entering the nuclear field and our workforce is ageing. Once we remove the burden of a negative public attitude, I am sure things will start changing.

However, last week I received an email reminding me and emphasizing problems in the developing world. So I decided to report here about the very interesting event that happened last June in our Nuclear Training Centre in Ljubljana. We had organized a training course about current and future reactor systems for participants from developing countries. Most of them were senior nuclear professionals from nuclear research centres with some years of experience running research reactors.

Towards the end of the course we asked participants to make a list of the top ten safety factors in nuclear energy. After half an hour about 20 items were listed on the board. The item ‘safety culture’ was included only after the very direct suggestions of lecturers. Then we started prioritizing the items. Surprisingly enough, most participants agreed for quite some time that the ‘containment’ was the most important feature of a nuclear plant for safety. Only after some challenging discussions did they realize that it could not be so. We ended up by putting safety culture at the top. The list of top safety factors had six items. Following safety culture were basic design, trained operators, quality assurance, organizational structure and regulatory system.

The whole exercise was very instructive to me. It was obvious that people in different countries with different cultural backgrounds have very different views on nuclear safety. We, people from the western hemisphere, talk about general principles of nuclear safety and safety culture. But are we sure that what we believe to be common understandings are properly understood everywhere in the world? Without a proper safety culture, no set of rules, no matter how prescriptive, will ensure safe operation. Some of our participants even worried whether their national culture, in which people routinely disregarded traffic laws, could ever be transformed into a different culture when they entered the nuclear plant.

Another surprise were the results of the final examination. Participants with a background in reactor physics, after two weeks of theoretical training, practical training at the research reactor and training on a simulator, were asked the following trivial question. A control rod is withdrawn from the critical reactor at a power level of 10 kW and re-inserted back to the original position after five minutes. After the transient, the power will stabilize at: (a) Less than 10 kW; (b) 10 kW; (c) more than 10 kW. Out of 20 participants, only 2 answered the question correctly! That was shocking and worrying. Some of those people are managers of nuclear installations back home and they do not know the basics!

We have today countries which have nuclear power programmes, but which, due to proliferation issues, are virtually disconnected from the rest of the nuclear power community of the world (India, Pakistan, the Islamic Republic of Iran). We also have countries, which are just thinking about entering into the nuclear power club, but have completely different cultural backgrounds (Indonesia, Viet Nam). After our small exercise in Ljubljana last June, I am sure that more has to be done in knowledge and safety culture exchange. We have to work on a system that would permanently motivate everybody to work on improvements. We have to offer to every country in the world equal opportunities for development in this area. The IAEA must play a leading role in this effort.

Panel Statement

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1. BACKGROUND

The JCO criticality accident in 1999 caused the general public to doubt whether the nuclear regulatory authority is competent enough to protect the public. In fact, residents near the nuclear fuel facility were forced to evacuate for two nights, and also two workers died of radiation exposure. Furthermore, in June 2001 residents in a small village near Japan's largest nuclear power plant voted to reject the use of MOX fuels in regular LWRs. This referendum is not legally binding, but the result may indicate a loss of public trust in regulatory activities.

Learning from the JCO accident and recognizing the importance of safety culture, the 'Reactor and Fuel Regulation Law' was amended and a new 'Special Law on Emergency Preparedness for Nuclear Disasters' was enacted. In order to monitor the licensee's compliance with safety rules approved by the Nuclear and Industrial Safety Agency (NISA), the number of regulatory staff was increased from 140 to 260, including 50 newly employed experts from the private sector with experience in the design of nuclear facilities.

In addition to the legislative reinforcement, the principles and polices for more effective regulation were discussed this year and confirmed in the advisory committee for NISA.

2. POLICY FOR EFFECTIVE REGULATION

The advisory committee for NISA studied the reports presented both from NISA and industries and concluded that the following policies were necessary:

(1) Regulation on the basis of up to date knowledge and experience in the design, construction and operation of nuclear installations, including fuel cycle facilities;

(2) Transparency of regulatory activities to increase public trust through an open approach and in accordance with the Public Information Access Law (in force as of 1 April 2001);
(3) Improvement of management compliance with authorized rules, and fostering of safety and quality cultures;
(4) Enhancement of international activities for constructive communication of good practices, standards, experience and knowledge with regard to regulatory activities.

3. CHALLENGES FACING NISA

The results of the studies for the advisory committee indicated that it is essential to improve the quality of NISA staff rather than merely increase their numbers. Staff with a high level of competence and experience can advance regulatory effectiveness and efficiency. Items 1–4 above are the challenges facing NISA.

In accordance with these policies, NISA is going to restructure the system of staff training and education and enhance international activities for collaborating with other countries in accordance with multilateral and bilateral agreements. Some advanced courses for greater expertise in safety are to be introduced, in addition to on the job training and basic courses.

Concerning international co-operation, review meetings for the Convention on Nuclear Safety and peer discussions on good practices are valuable in improving the quality of the regulatory staff. Furthermore, some indicators to be developed for regulatory effectiveness and efficiency may be used as part of the assessment of competence.

Panel Statement

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In 1992, Commonwealth Edison (now part of Exelon Corporation) approached the Office of Nuclear Energy in the United States Department of Energy (DOE) and proposed a 50–50 cost shared project to support university nuclear engineering education. Commonwealth would contribute $50 000 to five universities with nuclear engineering departments if the DOE would match that $50 000 at each institution. An agreement was reached and, although we did not know it at that time, the rebirth of the DOE's involvement in support of nuclear engineering education began. The DOE/Utility Matching Grant programme grew from that one sponsor and five schools to 35 sponsors and 25 schools this year.

This rebirth did not arrive any too soon. Although undergraduate student enrollments and the number of university research reactors had been in a modest decline for over a decade, 1992 would signal a cataclysmic decline in student enrollments that only recently has begun to ebb and even reverse course.

During the 1990s, the trends in nuclear engineering education and university research reactors were appalling and some drastic actions were required. Several studies conducted by university, industry and government panels reached the same depressing conclusion: the nuclear work force and university faculty were ageing and retiring, facilities were in need of maintenance or overhaul, student interest in nuclear engineering was extremely low and the public perception of things nuclear was one of disinterest or distrust.

After many missteps, the private sector, and especially universities and the Office of Nuclear Energy, began to work on establishing initiatives to revitalize nuclear engineering education in US universities; the private sector became more adept at presenting its case before the US Congress and financial assistance became a reality. Active leadership and involvement from the Director of the Office of Nuclear Energy, the establishment of a Nuclear Energy Research Advisory Committee and increased interaction with the university community through the Nuclear Engineering Department Heads Organization, the Test Research and Training Reactor Organization and the University Working Group resulted in a planned approach to both improving nuclear engineering education in the USA and the strengthening of university research reactors. Even with all of this, the momentum to merge nuclear engineering programmes with other engineering disciplines continued and research reactors continued to close, but by most measures the tide finally turned by the end of the millennium.

From that one initiative in 1992, the DOE Office of Nuclear Energy, Science and Technology has established no fewer than eight distinct programmes designed to assist nuclear engineering education, with many other smaller initiatives under way both domestically and internationally. One of our proudest accomplishments is our scholarship/partnership programme designed to attract minority students into the field of nuclear engineering. We also are planning to expand our programmes internationally, including new initiatives in Latin America.

We have a whole array of interesting programmes and ideas to share with IAEA Member States. Our outlook is positive and we want to sustain the momentum achieved over the past several years.

Panel Statement

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Let me start with a definition. Maintaining competence in nuclear engineering and nuclear safety means:

— Developing the necessary technical support, educational and research infrastructure, as well as a knowledge management system to meet all existing and emerging nuclear safety needs;
— Assessing that the infrastructure provides the desired outcome in spite of any new challenges.

However, problems in maintaining competence differ from time to time and from country to country.

Ukraine met the biggest challenge ten years ago when, after the Soviet Union's disintegration we feared that we would be losing a great deal of expertise and corporate memory. From the presentation of my Russian colleague, Dr. Morozov, you can realize how much. Fortunately, the problem was realized at the very beginning and was broadly discussed, and adequate measures were planned and implemented. So, after ten years:

— We have a basic technical support system both for operators and the regulatory body;
— We still have a research infrastructure, and one week ago the Cabinet of Ministers approved the concept of a national R&D programme for nuclear and radiation safety for 2002–2010 to be funded partially by the industry and by the government;
— We have four universities to educate nuclear engineers and about ten professional training centres for nuclear engineering and safety.

To a great extent we owe this to international co-operation, particularly the IAEA's technical assistance programme.

In fact, international co-operation seems to be a crucial factor in solving nuclear competence problems in countries without a proper technological background, especially in developing countries, which are more and more interested in nuclear energy these years. The IAEA's role in this regard is of great importance. To be sure, we have not solved all of the problems yet. But we know what to do and we have a plan to do it.

I would like to make reference to a previous session in this conference. I cite the statement of W. Renneberg: 'sufficient competence of nuclear operators had to be assured by themselves, not by the government'. While nobody argues with the issue of the operator's responsibility, the government is also responsible for developing the country's energy strategy to make sure that taxpayers have available a sustainable electricity supply without compromising safety. If the nuclear option is considered, the government should provide measures for maintaining competence as part of a governmental energy strategy.

SUMMARIES OF THE TOPICAL ISSUE SESSIONS AND THE PANEL DISCUSSION

Session 1

TOPICAL ISSUE No. 1: RISK INFORMED DECISION MAKING

1. CURRENT STATUS

There is general agreement that 'risk informed decision making' has the potential to contribute towards maintaining and improving nuclear safety. It can complement the deterministic approach to nuclear safety and maintain the concepts of defence in depth and adequate safety margins. The discussions clarified the fact that risk informed decision making is a broader concept than just the use of probabilistic safety assessment (PSA). Risk informed decision making uses the results of PSA as one input to the decision making process, but allows for consideration of other factors, in particular aspects of safety management and safety culture. At present these aspects are included in PSA only to the extent that they are reflected in the plant specific data used, but they are not explicitly modelled in PSAs. Risk informed decision making is a process which can be used by the utility and the regulator, and provides the framework for risk informed regulation. The objective is to enhance regulatory effectiveness, using risk information to optimize nuclear safety regulations by eliminating regulatory requirements that are shown to be unnecessary in the light of this information, and thus to reduce regulatory burdens.

Whether risk informed regulation is of benefit to utilities depends to a large extent on the common understanding developed with the regulatory authorities. Since the preparation of a PSA imposes a considerable burden, in terms of the human and financial resources that need to be expended, it is of the utmost importance to define clearly what is expected from the utility and how the results will be used. This common understanding can be developed in a dialogue that includes all stakeholders. Risk informed decision making will strengthen the perception that the operator is assuming the primary responsibility for safe operation.

Risk informed decision making in areas that affect licensee requirements necessitates review (and, ultimately, approval) of PSAs and supporting information by the regulatory body. A suitable regulatory framework and regulatory staff with considerable technical capabilities in the areas of PSA and risk informed decision making are prerequisites for such review and approval. This constitutes a considerable burden for countries with small nuclear programmes and limited numbers of regulatory staff.

There is de facto international agreement on the probabilistic safety criteria proposed by INSAG, both for existing and future nuclear power plants. These criteria take the form of targets for frequencies of core damage and large releases of radioactive materials. These targets are also referred to in the new IAEA Safety Standards publication, Safety Assessment and Verification for Nuclear Power Plants.[1] These targets have been established without specifying the scope or methodology for the PSA to be performed to demonstrate compliance with them. For risk informed decision making it is necessary to use as reference points more detailed, lower level criteria for specific purposes. Such criteria are in use in some countries.

It is necessary to ensure the availability of high quality PSAs to support risk informed decision making. The meaning of 'high quality' in this context can vary and is defined as being commensurate with the intended use. Several Member States have developed national PSA guidelines, and the IAEA has prepared PSA guidance at the international level. An American Society of Mechanical Engineers (ASME) standard on PSA is in preparation. Additional efforts to promote the production of high quality PSAs include peer reviews, establishment of user groups for similar type of plants, pooling of data and preparation of reference PSAs.

Risk informed decision making can be successful only if all stakeholders understand the process and the results obtained. The general public is an important stakeholder and it is necessary to find ways of communicating the results of risk informed decision making to them.

In addition to the main nuclear regulatory body, a licensee has to deal with several other regulatory organizations, e.g. those responsible for environmental protection. If the concept of risk informed decision making is not shared by these other authorities, this might complicate the decision process. Thus, consistency between the approaches followed by different authorities will be beneficial.

2. FINDINGS AND CONCLUSIONS

Depending on national situations and capabilities, some Member States are already well advanced in using risk informed decision making, whereas other countries are analysing the potential for and implications of its use. Therefore, it is important that information on both positive and negative experiences is made available, widely disseminated and analysed. The IAEA should contribute by compiling and analysing such experience with a view to developing guidance on the use of risk informed decision making to enhance regulatory effectiveness.

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment and Verification for Nuclear Power Plants, Safety Standards Series No. NS-G-1.2, IAEA, Vienna (2001).

In order to develop a common understanding between the regulator and the utility, it is important to establish a dialogue in developing risk informed regulations. This should clearly identify what is required from the utility and how it will be used in risk informed decision making. Examples were provided where such a dialogue has included other stakeholders representing public interests.

At present not all regulatory bodies are technically in a position to make use of risk informed decision making. The IAEA should give emphasis to including in its programmes training aimed at strengthening the relevant capabilities of regulatory bodies.

Risk informed decision making requires criteria to be used as a reference. There is international agreement on the probabilistic targets proposed by the International Nuclear Safety Advisory Group and referred to in the IAEA's safety standards. Work on compiling and analysing experience gained will necessarily include information on the criteria used.

It is necessary to ensure high quality PSAs to support risk informed decision making. To this end, the IAEA should give emphasis to developing guidance, supporting user groups, facilitating the collection and pooling of data and making available high quality reference PSAs. In addition, the IAEA should consider preparing a 'PSA quality guide', based on an analysis of national developments.

It is necessary to communicate the concept, methods and results of risk informed decision making to all stakeholders, including the general public. One important aspect is to communicate the change in regulatory decision making within the regulatory organization itself. The IAEA should consider compiling experience in the communication of such information, with a view to developing guidance on effective communication.

Effective use of risk informed decision making requires a consistent approach by the various authorities involved in regulatory decisions. The process of developing risk informed regulation should take account of these interfaces and involve those authorities in the process to establish consensus. The IAEA could compile examples of such interfaces and ways in which approaches have been made consistent.

Session 2

TOPICAL ISSUE No. 2: INFLUENCE OF EXTERNAL FACTORS ON SAFETY

1. CURRENT STATUS

The conference reached a general consensus that the external factors reviewed in the topical issue paper were real and would continue to exist and intensify for the foreseeable future. External changes and pressures are inevitable and the vital question is therefore how transitions and changes are to be managed. To maintain and enhance nuclear safety, it is necessary that safety performance, safety management and safety culture be fully embraced by operating organizations, and monitored by regulators (with appropriate interventions as required).

External change brings with it the opportunity for utilities to make significant internal change. For example, competition and deregulation have brought a new focus to economic performance, and a common response of utilities has been to improve the management of operations and maintenance and to improve the condition of plants. This has had a very positive effect on plant performance and reliability, and has also evidently enhanced the level of safety. Other responses by the industry have been changes in plant ownership, measures to cut costs and initiatives to reduce regulatory burdens.

Erosion of the technical infrastructure is a cause for concern, especially in countries where no new construction is taking place and where measures to modernize the operating plants are not being taken. Erosion is seen in reduced opportunities for university education in the nuclear field, decreasing investment in R&D, rapid degradation at the original plant vendors of the skills needed to support plant operation, and withdrawal of equipment suppliers from the market (the specific issue of maintaining competence was the subject of a separate panel discussion).

Political decisions on early closure of some plants have been made as part of national energy policies (for example, Germany and Sweden), and also under political pressure from other countries (for example, some European Union candidate countries). The main consequences seen today are reduced motivation among plant staff to strive for excellence and accelerated erosion of the technical infrastructure.

Inadequate financing of nuclear activities is a problem, especially in the countries of the former Soviet Union and in some other countries of Central and Eastern Europe. When revenues from power production cannot be collected and adequate Government funding is not available, it is difficult to make the necessary investments in plant condition and work practices and to have qualified, motivated staff working in the nuclear field.

The conference heard about a variety of changes taking place in the regulatory frameworks of different countries. Some of these changes are occurring in response to insights and experience gained over many years, and represent a maturing and refinement of the regulatory systems. In other cases the changes are more directly related to shifts in the external environment, such as the introduction of market competition for electricity.

A broad conclusion of the conference is, therefore, that although safety can be maintained through times of change, this will not happen by itself. It requires leaders who are knowledgeable, who are determined to give nuclear safety high priority, and who give their personal and visible support to the safety culture and safety standards of their organizations. In certain cases this may involve making some very difficult decisions, up to and including plant shutdowns. In all cases it means that the manner in which change is executed must be supportive of the safety culture. As a consequence, people who occupy senior roles in utilities, regulatory bodies and governments must have a respect for the hazards of nuclear power operations and a solid understanding of what is required to manage the risks.

2. FINDINGS AND CONCLUSIONS

— A solid safety culture throughout operating organizations is the best means to ensure safety in times of change. The IAEA should therefore continue its efforts to promote good management of safety and safety culture.
— New management approaches introduced in response to economic pressures have provided improved safety performance in many cases. The IAEA could arrange for the sharing of such positive experiences internationally between responsible organizations.
— While changes in organizational structures and ownership can clearly be managed so that they have a positive impact on nuclear safety, there is also a risk of deterioration in the safety culture if managers are not familiar with nuclear safety principles or if they do not demonstrate a positive and visible safety attitude to their organizations. The IAEA, together with other international organizations such as the World Association of Nuclear Operators and the OECD Nuclear Energy Agency, should therefore emphasize and promote a commitment to a strong safety culture among the corporate management of all organizations that are entrusted with responsibility for nuclear power operations.
— A lesson from other industries that have experienced deregulation, mergers and other major external changes is that these changes need not of themselves

threaten safety but that, because of their impact on the people in the organization, the transitions need to be well managed. Changed management processes and open communications should be applied during all major organizational changes, including, for example, reductions in staffing levels and major changes in structure.

— As seen in other industrial fields, open exchange of safety information is beneficial for all stakeholders and must not be reduced in response to the more competitive environment. The IAEA needs to continue to promote open communication between all organizations in the nuclear field.

— Maintaining a high level of safety is facilitated if organizations in transition can build upon a well established national culture that supports a positive attitude towards safety matters. However, organizations can have difficulties in countries where the society does not generally give high priority to safety. Guidance from the IAEA on how to improve the safety culture in such countries would be very valuable.

— Inadequate financing of nuclear power plants in many countries (in most cases due to the inability to collect revenues from power production) has created a situation that cannot be solved by the operating organizations or the regulators alone. Therefore, the concepts of safety culture need to be brought to the attention of the political decision makers at the highest levels, and the IAEA should elaborate the means for doing this.

— The most severe and widespread adverse impact on the capability to keep currently operational plants in a safe condition is probably the erosion of the technical infrastructure (including both technology and human capability). In addition, political decisions on early closure of nuclear power plants have created a situation where it is uncertain whether safe operation can be continued for the remaining operating lifetime. Safety cannot be ensured by strict regulation alone if the operating organizations have lost their motivation and skills, or if they cannot get technical support and spare parts from external sources. It was recommended that the IAEA assist in bringing these issues to the attention of the decision makers, who may think that the current generation of plants can safely operate to the end of their designed life even if the technical infrastructure is lost.

— Operating organizations have the responsibility, and the best capability, to respond to changing situations quickly. Therefore, regulatory organizations should preferably provide only a general framework for the changing activities of the industry, while observing what the industry is doing. Open dialogue and close interaction between the highest levels of management of operating organizations and regulatory bodies is necessary and commendable to ensure that both parties have a mutual understanding of the direction and the limits of new developments. This open dialogue is vital for building mutual trust between the regulators and the operators which, in the wider view, is a necessary part of improving the effectiveness and efficiency of regulation. The IAEA should provide a forum and guidance in this area.

— There would be value to both utilities and regulators in having tools available for assessing the effectiveness of management systems in maintaining safety through transitions. There was no consensus on whether the regulators would need to perform such assessments themselves, or could require that the utilities perform the assessments and present the results. In either case, there was agreement that experience with such assessment methodologies should be shared, and the IAEA should assist in this area.

Session 3

TOPICAL ISSUE No. 3: SAFETY OF FUEL CYCLE FACILITIES

1. CURRENT STATUS

Fuel cycle facilities include a broad range of installations covering all of the processes needed to produce, use and reprocess nuclear fuel. The number of such facilities (excluding reactors and waste disposal facilities) worldwide currently exceeds 500, and is increasing. Although the radioactive source term for most fuel cycle facilities is lower than that for reactors, and therefore the potential radiological consequences for the public in the event of an accident may be less severe, recent events at some fuel cycle facilities have given rise to renewed public concern, which has to be addressed adequately by national regulatory bodies and at the international level. Some countries are currently revising their national regulations as they apply to fuel cycle facilities.

There is general agreement that many of the safety concepts applied to nuclear power plants are equally applicable to fuel cycle facilities. Recent experience gained with the safety enhancements of nuclear power plants could provide a valuable input when safety improvement measures are proposed for fuel cycle facilities. The discussions focused on some particular examples, such as periodic safety reviews, establishment of safety management, and promotion of safety culture, and it was pointed out that the exchange of information on these subjects could be of mutual benefit to operators of both nuclear power plants and fuel cycle facilities.

However, it was acknowledged that there are numerous differences between nuclear power plants and the variety of fuel cycle installations. In fuel cycle facilities, fissile and radioactive materials are handled, processed, treated and stored throughout the entire installation. These facilities also rely to a great extent on operator intervention and administrative controls to ensure safety. Specific safety concerns include criticality, radiation protection of workers, chemical hazards, fires and explosions, and the implications of human factors, all of which need to be addressed in an adequate manner in the design and operation of the plants. The safety standards for fuel cycle facilities which the IAEA plans to develop in the next few years will build on established standards and on international consensus regarding the safety requirements and guidance for different types of such facilities.

It was acknowledged that the development of safety standards is a prerequisite for the IAEA to provide adequate safety services to assist Member States in enhancing the safety of fuel cycle facilities. There is a need for the IAEA to review its existing safety services and consider adapting them where appropriate to enable them to be used directly for fuel cycle facilities.

It was recognized that a significant factor in enhancing the safety of any nuclear installation is the continuing worldwide exchange and analysis of safety relevant information and data. However, it appears that, with respect to fuel cycle facilities, this process is mainly limited to countries with well developed nuclear power programmes. The lack of records in international databases on incidents and accidents in other countries should not be taken to suggest that feedback of operational experience is not considered by the facilities in operation in these countries. However, in order to maximize the benefit, it would be helpful if all Member States provided operational experience feedback so that valuable lessons learned can be shared with the wider international nuclear community.

2. FINDINGS AND CONCLUSIONS

— The Member States of the IAEA should be supported, when requested, in identifying national needs in relation to the safety of fuel cycle facilities.
— The IAEA should continue to provide a focus for promoting the safety of fuel cycle facilities by establishing adequate safety standards and by supporting Member States in developing their capabilities in this area. It is important to develop and publish the appropriate IAEA safety standards for fuel cycle facility safety in a timely manner so that they can be used as a basis for IAEA safety services.
— The IAEA should review its existing safety services for nuclear power plants and research reactors and adapt them where appropriate to enable their use for fuel cycle facilities. It is understood that some of the services, such as the International Regulatory Review Team and International Probabilistic Safety Assessment Review Team, could easily be applied to fuel cycle facilities as well, whereas others, such as Operational Safety Review Teams (OSARTs) and design review services, may need significant adaptation. It is suggested that observers from fuel cycle facilities be invited to participate in future OSART missions for nuclear power plants so that they can become acquainted with the procedures and approaches used. This will also promote the exchange of information on operational safety assessment between nuclear power plants and fuel cycle operators.
— The IAEA should provide guidance and assistance to Member States as appropriate to carry out periodic safety reviews, taking into account the experience gained in carrying out such reviews for nuclear power plants and for some fuel cycle facilities.

— The IAEA should continue its work of fostering the international exchange of information on regulatory and safety issues for fuel cycle facilities. It is recommended that the IAEA build on its long standing activities in event information exchange and analysis for nuclear power plants (the Incident Reporting System, NEWS and the International Nuclear Event Scale) to fulfill the same role for other installations of the fuel cycle and seek co-operation with the OECD Nuclear Energy Agency on its FINAS database. Action should be taken to collect and disseminate to all interested Member States the experience and lessons learnt.
— Recognizing that training and qualification of the personnel who operate fuel cycle facilities is crucial to safety, it is recommended that the IAEA develop and hold training courses on the safety of fuel cycle facilities. It is also suggested that the IAEA explore the possibility of using existing experimental facilities in France, the United Kingdom and the USA for criticality safety training of operators from other countries. Experiments at such facilities may also be used to fill some gaps in knowledge of criticality safety.
— The IAEA is encouraged to adapt the experience gained from the establishment and application of safety performance indicators for nuclear power plants in order to assess Member States in the development of safety performance indicators for fuel cycle facilities. It is also recommended that the recent actions taken by the IAEA to support Member States in the safety management assessment and promotion of safety culture for nuclear power plants be expanded to cover fuel cycle facilities.

Session 4

TOPICAL ISSUE No. 4: SAFETY OF RESEARCH REACTORS

1. CURRENT STATUS

Research reactors throughout the world represent an extremely diverse set of facilities. This diversity applies to aspects such as design features, suppliers, age, power level, fuel enrichment, safety culture, utilization programme and regulatory supervision. Most research reactors are in need of effective ageing management. Among the population of research reactors there are some that are heavily utilized, well funded, well regulated, well maintained, well staffed with well trained operators and operated within a strong safety culture. Many research reactors are under-utilized but well regulated or operated within a strong safety culture, giving due attention to ageing management and long term staffing. While most research reactors are believed to be in one of these two categories, Topical Issue Paper No. 4 concentrates on the relatively small number of exceptions. There is evidence that some facilities are inadequately funded, are operating with inadequate regulatory supervision, lack effective programmes for managing ageing, or have no strategic plan for the replacement of ageing staff. The IAEA's database is not sufficient to identify the exact number of research reactors in this category or the extent of the deficiencies. However, it is recognized that the paper focuses on a small segment of the population of research reactors.

Research reactor safety is gaining in importance within the general scope of nuclear installation safety worldwide. The IAEA has developed and offers various programmes to assist Member States in enhancing the safety of research reactors, such as the Integrated Safety Assessment of Research Reactors (INSARR) and International Regulatory Review Team (IRRT) services, and the Incident Reporting System for Research Reactors (IRSRR).

INSARR and IRRT missions provide recommendations, which the requesting Member State may consider and may implement. However, there is no mechanism to ensure that recommendations are being implemented. The IRSRR is now operational, but the level of participation by Member States is not extensive.

The IAEA bases its activities in part on survey results, but its database on research reactors does not contain sufficiently detailed information on aspects relevant to the safety of facilities in extended shutdown.

The status of more than two-thirds of the 370 or so research reactors that have been shut down is unclear, pending decisions on their future. Decisions need to be made about whether a reactor will return to power at some time, or whether it should be decommissioned. Indecision may result from factors such as the lack of a clearly defined utilization programme, insufficient funds for continued operation or the perceived high cost of decommissioning.

While there is regional co-operation and regional centres exist among the large research reactors, there is very little regional sharing among the smaller research reactors. If a country cannot provide sufficient funding for continued operation of its reactor, this may be an option to consider. If a country has a reactor in extended shutdown, the decision to decommission may be easier if a regional centre is available to provide the limited utilization that the country requires. However, in view of the complexity of some issues — particularly issues of funding — more information on the regional centre concept is needed.

Historically there has been an interdependence between research reactors and power reactors. In the past, research reactors have been used to generate technical data and to test materials critical to the design and operation of power reactors, and research reactors are still widely used in the education and training of new personnel. Today, power reactors have resources that would be of value to research reactors, such as expertise in quality assurance and safety culture. Research reactors can also benefit from observing good practices in effect at other research reactors.

The conference was in general agreement with the assessment made in Topical Issue Paper No. 4 and the conclusions drawn.

2. FINDINGS AND CONCLUSIONS

(a) Statements characterizing the problems being experienced at some research reactors should not be generalized as being applicable to all facilities.

(b) In parallel with actions pursuant to items (c)–(g) below, since a convention on research reactor safety is not acceptable to all Member States, at least a code of conduct should be established to serve as a model against which all research reactors might evaluate their safety programmes.

(c) The IAEA should especially focus its assistance activities on areas such as quality assurance programmes, enhancement of safety culture, ageing management and safety management.

(d) The IAEA should conduct a survey requesting information from Member States to better characterize the safety aspects of their research reactor facilities.

(e) Member States and reactor manufacturers should be encouraged to share information about known safety problems with facilities of similar design throughout the world which could be subject to the same problems.

(f) Member States are encouraged to request INSARR and IRRT services from the IAEA, and to take action on the recommendations provided by these services.

(g) Member States are encouraged to participate in the IRSRR.

(h) Operating organizations should be encouraged to develop strategic plans on the future utilization of their reactors which will help Member States with facilities in extended shutdown in making decisions on whether or not to terminate operations. The plans should examine the options that are realistically available for the reactor's future, determine whether anticipated utilization justifies restarting of the reactor, and look at the sources and availability of necessary funds. Reactors that might return to power must be adequately maintained in accordance with their licences and operational limits and conditions, and an adequate pool of expertise must be retained.

(i) Member States should ensure that effective regulatory supervision exists for their research reactor facilities.

(j) The concept of regional centres should be investigated further with a view to providing an alternative for Member States desiring research reactor utilization services but not the burdens of meeting all of the facility's operating costs and maintaining a regulatory supervision programme.

(k) The IAEA should provide guidelines for research reactors on extended shutdown requirements, criteria for restart from extended shutdown, radioactive waste treatment, and disposal and decommissioning planning.

(l) In deciding on the timing for decommissioning, Member States should note the limited opportunity for acceptance of irradiated fuel by the USA and, possibly, the Russian Federation.

(m) Research reactor management should take advantage of good practices developed and implemented at other research reactors or at power reactors through observation, peer exchange programmes and training. The IAEA should continue to offer its safety review services for research reactors and build up its experience from nuclear power plant review services.

Session 5

TOPICAL ISSUE No. 5: SAFETY PERFORMANCE INDICATORS

1. CURRENT STATUS

It is generally agreed that in order to have a complete safety management system, a comprehensive set of safety performance indicators (PIs) must be used, in combination with other insights such as safety culture and human performance evaluations, inspections and audits, risk analysis, feedback of experience and other external review and self-assessment tools.

Experience accumulated to date includes the World Association of Nuclear Operators (WANO) PI system, the United States Nuclear Regulatory Commission's new Reactor Oversight Program, and various individual initiatives of operators and regulators. This makes it possible to identify both the benefits associated with the establishment and use of a safety PI programme and the precautions which need to be taken. Despite the difficulties that can be encountered when defining goals and performance bands for each PI, it is clear that the establishment of thresholds, goals and performance bands contributes to the effective use of safety PIs by regulators and operators.

The IAEA has developed a framework for the establishment of plant specific operational safety PIs. The framework was tested by the operators of four nuclear power plants, who found it to be a good approach for establishing comprehensive safety PI programmes. Following the publication of IAEA-TECDOC-1141,[1] additional nuclear power plants in different countries have adopted this framework and have adapted it to serve their own needs and to suit their plant processes, data collection systems and previously existing safety PI systems. This work is continuing in the framework of an IAEA Co-ordinated Research Project.

To date, the most common way of monitoring the safety culture of a nuclear organization is to perform comprehensive qualitative safety culture surveys. It seems clear that it is not possible to define a unique, direct, quantitative indicator to measure the state of safety culture. However, it is possible to identify a portfolio of indicators

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Safety Performance Indicators for Nuclear Power Plants, IAEA-TECDOC-1141, IAEA, Vienna (2000).

to measure the characteristics of a positive safety culture. This work is ongoing in the framework of the IAEA's activities.

Degradation in the safety management process has occurred in several nuclear organizations and some common symptoms have been identified. These symptoms can be used to develop safety PIs that will be of practical value in detecting adverse trends from both a utility and regulatory perspective.

Nuclear power plants that have established comprehensive safety PI programmes are able to use them to gain a good understanding of the safety performance of the plant, to identify signals of deterioration and, thus, to allocate resources where they are most needed, giving due consideration to the safety implications.

Regulators can benefit from the formal adoption of safety PI programmes. In order to identify a complete set of safety PIs for regulatory use, the overall areas of the operational safety of nuclear installations need to be identified. Each of these areas can be characterized by a small set of indicators which could be selected from those collected by the plant. A set of these safety PIs could perhaps be used to effectively communicate nuclear safety in an understandable manner to the public.

2. FINDINGS AND CONCLUSIONS

The following aspects were addressed:

— A comprehensive set of safety PIs is necessary to obtain a good picture of the safety performance of a nuclear installation. However, these PIs should not be used in isolation. A safety PI system provides a proactive approach to complement other safety assessment tools.
— Safety PIs should be able to provide early warnings of deterioration in performance. Therefore, leading as well as lagging indicators are required. Identification of the indicator evolution (trend analysis) is fundamental to accomplishing this objective. In addition, it is believed that targets and thresholds play an important role in the evaluation of indicators and should, therefore, be adequately defined. Engineering judgment and/or existing quantitative tools have to be used to understand the risk implications associated with the behaviour of the indicator.
— A plant specific set of safety PIs is a valuable tool to enhance safety performance, help avoid complacency and help plant management to determine what requires attention. Therefore, each nuclear installation has to select the most appropriate set of indicators. Furthermore, this set should not be static.
— The framework proposed in IAEA-TECDOC-1141 provides a good approach for establishing a comprehensive operational safety PI programme and can help

nuclear installations to achieve the objectives discussed in the previous paragraphs.

— There is often a delay between the development of weaknesses in the safety culture of an organization and the occurrence of events with significant safety consequences. Thus, by being alert to the early warning signs, corrective actions can be taken in sufficient time to avoid adverse safety consequences. However, monitoring safety culture by traditional quantitative indicators is not straightforward. Therefore, nuclear installations need to perform periodic qualitative evaluations of the safety culture of the organization and may find it useful to identify additional quantitative indicators to monitor this area.
— Indicators to monitor the safety performance of nuclear installations are important inputs to the regulator's work. Key safety aspects to be monitored by the regulator need to be identified in order to develop a complete set of indicators.
— Further work is required to define a subset of the indicators used by nuclear operators to inform the public on matters of safety and to build trust. The current views and approaches in different countries differ significantly with regard to the amount and form of information that should be provided.
— Further work is required to harmonize indicators before they can be used internationally.

The following recommendations can be inferred from the discussions:

— Nuclear installations are encouraged to develop plant specific operational safety PI programmes. Experience to date indicates that the IAEA approach provides a good framework for this purpose.
— Safety PIs should be complemented by periodic qualitative evaluations of the safety culture and safety management in the organization.
— A framework and set of safety PIs which could be used by regulatory bodies should be developed as a follow-up to the work already done by the IAEA (the IAEA has already included this task in its work programme for 2002–2003).
— The development of an international set of safety PIs would require an assessment of what is truly common across the industry and further experience in the application of safety PIs by regulatory bodies.
— The IAEA is encouraged to investigate indicators which are common to various kinds of nuclear facilities, and to promote their utilization within a consistent framework.
— In order to build public trust, nuclear operators must ensure that safety PIs used for public information are transparent and understandable, and are not subject to manipulation.

In summary, positive trends and values of safety indicators cannot fully eliminate the risk of accidents or incidents. However, the use of safety PIs is an effective way to help in enhancing the safety of nuclear installations.

Panel

MAINTAINING COMPETENCE

1. CURRENT STATUS

The nurturing of an effective safety culture needs competent staff throughout an organization, that is staff who have the necessary education, knowledge and dedication and who care about safety. The nuclear industry is facing a situation in which many of the most experienced and knowledgeable individuals have retired or are approaching retirement, while the number of young people embarking on careers in the industry is declining. If the industry is to continue to operate safely, and even grow in the future, it needs not only to replace the lost staff, but also find ways of retaining the wealth of knowledge and experience accumulated by those staff during their careers so that it is available to their replacements.

There is a widespread general decline in interest in careers in the physical sciences and engineering. Furthermore, the stagnation or decline of nuclear power in many countries and the often highly negative image of the nuclear industry have together made nuclear science and engineering even less attractive. As a result, educational opportunities available in these fields are declining: fewer universities are offering relevant specialized courses because they cannot attract enough students. In addition to the loss of courses, many of the research reactors associated with these universities are also being shut down.

It was also pointed out that simple question and answer sessions have shown that many present day operators lack an in-depth understanding of reactor physics and the principles of reactor operation. Without such an understanding there can be no effective safety culture. This emphasizes the need for better education.

Although a particular problem has been identified in relation to university education, the need to maintain — and indeed enhance — competence is much more general. True competence requires the fundamental understanding, specialized skills and real world knowledge that come from a proper combination of education, training and experience. Furthermore, competence is needed not only at the level of the professional nuclear engineer, but throughout the whole work force.

Some countries have historically ‘imported’ expertise, and many nuclear safety professionals educated and trained in one country have made their careers in another. Given the general trend towards globalization, and the different prospects for nuclear power in different countries, this mobility of nuclear professionals might be expected to increase, and could make a significant contribution to the solution of the problem of maintaining competence by providing an external source of expertise. The prospect of an ‘international’ career might even attract people to the industry who otherwise might not consider the nuclear field. However, if this international mobility was predominantly in one direction (e.g. from developing countries to developed countries), it could exacerbate the problem of maintaining competence in the countries of origin.

Following the recommendations of an international Advisory Group, the IAEA is modifying the focus of its education and training programmes in nuclear safety. While continuing to only provide a wide range of courses, in parallel they are placing more emphasis on helping countries to build the infrastructure for their own sustainable national education and training programmes and on providing materials to allow countries to organize their own courses in accordance with the IAEA’s safety standards.

2. FINDINGS AND CONCLUSIONS

The nuclear safety field must find ways to attract more talented young people. To some extent, this may only be achievable by improving the overall perception of the nuclear industry. However, the challenges and opportunities of nuclear safety also need to be presented in a more attractive and exciting way. International networking or exchanges between students and young professionals can help to build enthusiasm.

Measures need to be taken to preserve the ‘knowledge base’ held by long serving staff that have recently retired or are approaching retirement, and to transfer it to the next generation. Various methods are available, such as ‘mentoring’ of young staff by those approaching retirement, or ‘archiving’ information on various media, but these need to be applied more widely and systematically before it is too late. This must be done at the local level, but the IAEA could help to disseminate information on the different methods used and experience gained. The IAEA could also help to provide guidelines on appropriate methodologies that could be used to capture and organize this information.

Operating organizations and regulators need to systematically identify the core competencies that will be needed to ensure the safety of nuclear installations in the future, and make plans to provide for them. Although operators have the primary responsibility for safety, governments have a role to play in ensuring that the basic infrastructure is available to allow competence to be maintained. The IAEA could help to foster the exchange of national experience to assist countries in performing this task.

Examples of how this is being achieved include the collaboration between the United States Department of Energy and the power utilities that has resulted, thus far, in eight distinct programmes designed to support departments of nuclear engineering. These programmes will also be expanded internationally. Some initiatives have also been undertaken in the United Kingdom to support a programme at the University of Birmingham.

There is evidence that the decline in numbers of students entering the nuclear field can be stopped and possibly even reversed if operators, regulators and governments co-operate with universities in identifying which courses are needed, in assisting with these courses and in providing some positive encouragement (e.g. bursaries) for potential students.

Research reactors are valuable resources for training and for obtaining practical experience, but many are being lost because of under-utilization. The IAEA could extend the idea of regional centres for education and training by supporting the use of research reactors as ‘regional centres’. These regional centres for post-graduate education in radiation protection are proving to be very valuable, and the IAEA could consider extending this concept to cover education in nuclear and waste safety.

The IAEA’s initiatives to promote sustainable national and regional infrastructure for education and training in nuclear safety are welcomed. The quality of educational and training courses is also essential. The IAEA’s emphasis on developing ‘model’ courses that are consistent with its safety standards is a positive development in this regard and should be continued. This approach might also be extended to provide some form of international accreditation system for national educational and training programmes.

3. MAIN POINTS

The following important points emerged from this panel discussion:

- To operate safely, and particularly to have an effective safety culture, it is vital to maintain a high level of competence throughout an organization.
- Education, training and the husbanding of accumulated experience all play an important role in this process.
- For a variety of reasons the recruitment of competent young people to the industry has fallen to a very low level and in some countries this may be reaching the proportions of a crisis.
- It is clear that in the interests of safety, governments and utilities must play an active role in reversing this trend. This is already happening in some countries such as the USA and, to some extent, in the United Kingdom in the form of co-operation between utilities, government and universities.
- For nuclear energy installations to continue to operate safely and perhaps even to grow in the future it is essential that these initiatives, as well as other initiatives being undertaken inter alia in Japan, Ukraine, Slovenia and South Africa should all be pursued vigorously.

— The IAEA has an important role to play in encouraging and facilitating this process.
— It can assist in the establishment of model curricula, for example for post-graduate education at institutions for higher education. It could play a role in facilitating a process of international accreditation.
— It can assist in the establishment of regional centres, both for education and for the effective utilization of research reactors in education and training.
— The IAEA can investigate and disseminate methodologies (possibly ‘expert systems’) for the retention of practical knowledge and experience.
— Finally, this is an international problem and the international mobility of experts can play an important role in maintaining competence in the nuclear industry.

CLOSING SESSION

Chairperson

J. BRONS
United States of America

CLOSING STATEMENT

COMMUNICATING MEETING RESULTS TO THE PUBLIC

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I have the difficult task of how to communicate this meeting's results to the public. No convention was signed this week on nuclear safety; there is nothing particular to report that would make major headlines. However, I did the following exercise and tried to find 'sound bites', bringing out things that I had heard and observed that could be positive communication themes.

This conference brought together a prestigious gathering of people from all sectors of the nuclear community:

— There was very good attendance, with 181 participants from 48 countries, resulting in excellent geographical coverage. This shows that obviously IAEA Member States are very interested in the topic of safety, and that is a very positive message. Nuclear safety benefits from good international co-ordination.

— I also observed that this meeting was an excellent venue for an exchange of information.

— As far as the IAEA was concerned, I got a strong sense that it wanted to get feedback on how it could help and do more and better in order for Member States to achieve their objectives in terms of nuclear safety.

— I also was very encouraged that the results of this meeting will be communicated to the Board of Governors and to the General Conference within the next couple of weeks. This, to me, is also a very positive outcome.

— When I looked to see whether the objectives of this meeting had been met, I would say that they had, as I had witnessed an exchange of information and a consolidation of international consensus. 'Consolidate' is not the same as 'achieve'. I do not think we *achieved* international consensus — that would be something extremely difficult to do. But at least we have a forum to discuss the present status, the priorities for future work and recommendations for future IAEA activities. In that sense, I felt it was very positive.

Let me tell you some of the exciting parts I heard. There were some positive messages and I have already mentioned international co-ordination. There is also the fact that we have a dialogue between the different sectors of the nuclear community working in the field of nuclear safety, i.e. the regulators, the utilities and the operators of research reactors and fuel cycle facilities, all discussing safety. I understood this to be rather rare — maybe not rare but not as frequent as one would hope. Indeed, I felt more reassured about the issue of managing safety in a changing market. We heard about the privatization of the sector and its consequences, as well as decommissioning, and that safety — regardless of all this — was always a priority. For me that was a positive message.

This conference was an opportunity also to highlight areas of improvement. It allowed for frank discussion, and emphasized the need for improved communication between regulators and utilities, in particular when safety requirements have to change. There was also a consensus in terms of safety culture and safety management — also a very positive sign.

Now for the ‘bad news’. The communication pitfalls or communication challenges were as follows:

— I heard here that not all Member States are taking IAEA conventions seriously. If I had to communicate on this topic, it would certainly be a very delicate subject.
— I also heard here that there are two vulnerable areas in terms of safety standards: decommissioning and waste. These are topics that we have to deal with as communication professionals. Waste is one subject about which I hear almost every day; decommissioning a little bit less often. But, if we are vulnerable in terms of safety, then that is definitely going to haunt us.
— Fuel cycle facilities and research reactors do not have the same high quality safety levels as nuclear power plants. That was a surprise for me to hear.
— There is also concern about ageing facilities. This is going to be a difficult subject to communicate. The general public is already worried about power reactors and research reactors, but the ageing of facilities is a vulnerable subject for communication, and is certainly an area of concern. Would funding problems jeopardize safety if some countries found that they did not have the finances to keep ageing facilities at the right safety level?
— Regarding the German phase-out, the differences of opinion among people addressing this topic make it a real communications nightmare.
— A further point involves ensuring future expertise and finding the next generation of engineers at a time of decreasing R&D funding. How would we meet the challenges of a nuclear renaissance in terms of human resources and funding? My own perception is that if we see that different countries are deciding to build nuclear power plants, then we will naturally see more students

coming into nuclear education and training programmes. So perhaps I do not feel quite as desperate as some people in this room.

One other important theme was something I have noticed before, and which was just confirmed here. That is that we tend to be too insular in the nuclear community. This point was brought up by Claude Frantzen (Electricité de France) in a way that was very strong and convincing, when considering probabilistic safety assessment, for instance. If we look at other industries and work with them, we become a bit more like one of the many industrial players in the world. It is much easier than treating ourselves as sort of ‘separate and special’. ‘Special’ means, in this case, more difficult. It is part of the challenges we have to act upon. I mentioned the risk management question, but I think that bringing nuclear energy into the mainstream relates to many of the areas we work in.

These are just the observations of an onlooker; I hope my comments help to put things in perspective.

CHAIRPERSON'S CLOSING STATEMENT

SUMMARY OF THE CONFERENCE

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Ladies and gentlemen, I have the honour now at the end of this conference to summarize the significant achievements of this conference. Before I begin, I want to thank the members of the programme committee who guided the development of the papers for this conference over the last year: K. Cosenza of Brazil, J.P. Laurent of France, Young Soo Eun of the Republic of Korea and B.Winkler of South Africa. The original chairman of this conference, T. Mikus of Slovakia, also made important contributions until he was forced to withdraw about six months ago because of greater responsibilities in his home land.

The first discussion revealed broad agreement that where the capability exists, risk informed decision making can be a significant enhancement to nuclear safety and the safety focus. It was acknowledged, however, that existing frameworks of deterministic regulations are also effective. It was clear that undertaking the work to produce an underlying plant specific probabilistic safety assessment (PSA) of sufficient quality to achieve some or all of the potential benefits of risk informed decision making could be a real burden in some situations. The conference also noted that achievement of the benefits requires alignment between the regulatory body and the power plant on the use and understanding of this advancement.

It was recommended that the IAEA supplement its existing international level guidance regarding PSA with new work to assist Member States who want to adopt this concept. The IAEA was asked to provide guidance and assistance for both operators and regulators regarding training, reference criteria, global experience and communications programmes for use, when appropriate.

A wide range of views regarding the influence of external factors on nuclear safety was expressed. Indeed, the expression of some views reflecting current political decisions during the course of the discussions demonstrated in a small way the potential for distracting both operators and regulators from a sharp focus on safety.

Important discussions on the impact of market liberalization, a significant external factor, revealed that in those regions where the achievement of strong business performance is recognized to be a natural result of strong safety performance this external factor may enhance safety. In those countries where the power plant is unable to benefit from its own excellence of operation, the safety culture cannot be strengthened by this external factor or through actions of the regulatory body or the operating organization acting alone. It was recommended that the IAEA elaborate means for bringing this and other factors to the attention of the highest political decision makers.

The most significant conclusion from this session, however, and one which impacts every topic discussed in the conference was that a strong safety culture in a nuclear facility is paramount. The existence of a strong safety culture will enable organizations to tolerate change and withstand many external pressures. The IAEA was asked to intensify its efforts to identify ways to develop, identify, measure and promote a strong safety culture within nuclear facility operating organizations. The conference noted that this need is particularly urgent in some countries where safety is generally not given a high priority in society.

The discussions on fuel cycle facilities recognized that although there are many differences between these facilities and power plants, there are many significant common elements as well. The conference suggested that the IAEA enhance its preparedness to respond to requests for assistance from Member States for fuel cycle facilities. The development of appropriate safety standards is a prerequisite to providing these safety services. The IAEA should consider elements of its assistance programmes currently in use for power plants for application with qualified peers at fuel cycle facilities, and foster international information exchange on performance, safety and safety indicators. The possibility of including some representatives of fuel cycle facilities in Operational Safety Review Team (OSART) missions is also suggested.

On the subject of the safety of research reactors, it was recognized that the most important audience was not present at the conference. Specifically, operators running reactors without regulatory oversight, and possibly without sufficient safety focus or sufficient funding. Mindful of this situation, the conference discussed issues of ageing and extended shutdowns in the absence of plans for future use or decommissioning. The importance of ensuring strong safety cultures at research reactors was recognized, and the IAEA was asked to focus research reactor activities on programmes such as quality assurance that enhance safety culture and safety management. Operating organizations with reactors in extended shutdown should be encouraged to develop strategic plans for the future of these facilities considering realistic outlooks and the sources of necessary funds.

The IAEA was also asked to conduct a survey of the safety aspects of research reactors, and to investigate further how the needs of Member States could be served by regional centres. This might permit an alternative when decommissioning is being considered.

Maintaining a competent work force for both nuclear facilities and for regulatory oversight is recognized to be a significant issue. It was the subject of a separate session.

Widespread agreement exists that the number of young people interested in the technical work associated with infrastructure industries is declining. This shortage can be seen both at the craftsman and the degreed engineer levels for many disciplines associated with nuclear facilities. Simultaneously, the industry is facing a significant loss of existing competence because a disproportionate share of the work force is reaching retirement age. This is particularly true in engineering areas.

Many different approaches are being taken by regulators, nuclear installations and governments of Member States to make careers and education in pertinent fields more attractive. The IAEA was asked to monitor these efforts, foster the exchange of national experiences and disseminate information on the methods used and experience gained to all Member States. It should also continue its work to enhance the quality of nuclear training and the development of model courses. The possibility of establishing regional centres for education linked to regional research reactors should be considered.

Safety performance indicators (PIs) are widely used by nuclear enterprises. Many indicators are used by managers and regulators to measure and monitor the details of operational performance. Often, these indicators are expressed in technical terms that do not lend themselves to two important objectives. One is the measurement of safety and safety culture, and the other is to communicate the overall quality of nuclear operations to the public.

The conference addressed the difficult — but not impossible — task of defining a small set of indicators with international uniformity and relevance that can be useful to operators, regulators and the public. Our discussions revealed the difficulty of the task and the time required to accomplish it. Some expressed the view that extreme care should be exercised in this regard.

It was clear that measurement systems and indicators are important. Objective measures should be used by both plants and regulators. The IAEA should continue its work to ensure that objective PIs are available for effective use at all nuclear power plants. Further, the IAEA should continue the task of identifying and testing indicators which can have international relevance and uniformity, for use by all interested stakeholders.

The use of indicators to assess risk relevance was also discussed. This too was seen as difficult. However, given its application in some Member States, it was suggested that work proceed, aided by appropriate research.

Now that we have completed our work and set forth sound recommendations for future work to enhance the safety of nuclear facilities, it is time to thank all of you. To the session chairmen, the rapporteurs, the keynote speakers, the presenters of lead-in discussions, the authors of contributed papers and posters, to the speakers at special sessions and panels and to all who contributed perspectives during our discussions, I say thank you. It was a worthy effort.

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